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U.S. METRIC STUDY INTERIM REPORT

EDUCATION

U.S. METRIC STUDY

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The results of substudies of the U.S. Metric Study, while being evaluated for the preparation of a comprehensive report to the Congress, are being published in the interim as a series of NBS Special Publications. The titles of the individual reports are listed below.

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U.S. METRIC STUDY INTERIM REPORT

EDUCATION

Sixth in a series of reports prepared for the Congress

U.S. METRIC STUDY
Daniel V. De Simone, Director

National Bureau of Standards
Special Publication 345-6

UNITED STATES DEPARTMENT OF COMMERCE
MAURICE H. STANS, *Secretary*
NATIONAL BUREAU OF STANDARDS
LEWIS M. BRANSCOMB, *Director*

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LETTER OF TRANSMITTAL

THE HONORABLE PRESIDENT OF THE SENATE
THE HONORABLE SPEAKER OF THE HOUSE OF REPRESENTATIVES

SIRS:

I have the honor to present the sixth in the series of interim reports stemming from the U.S. Metric Study, prepared by the National Bureau of Standards.

This Study was authorized by Public Law 90-472 to reduce the many uncertainties concerning the metric issue and to provide a better basis upon which the Congress may evaluate and resolve it.

I shall make a final report to the Congress on this Study in August 1971. In the meantime, the data and opinions contained in this interim report are being evaluated by the Study team at the National Bureau of Standards. My final report to you will reflect this evaluation.

Respectfully submitted,

Maurice H. Stans

Secretary of Commerce

Enclosure

LETTER OF TRANSMITTAL

Honorable Maurice H. Stans
Secretary of Commerce

Dear Mr. Secretary:

I have the honor to transmit to you another interim report of the U.S. Metric Study, which is being conducted at the National Bureau of Standards at your request and in accordance with the Metric Study Act of 1968.

The Study is exploring the subjects assigned to it with great care. We have tried to reach every relevant sector of the society to elicit their views on the metric issue and their estimates of the costs and benefits called for in the Metric Study Act. Moreover, all of these sectors were given an opportunity to testify in the extensive series of Metric Study Conferences that were held last year.

On the basis of all that we have been able to learn from these conferences, as well as the numerous surveys and investigations, a final report will be made to you before August 1971 for your evaluation and decision as to any recommendations that you may wish to make to the Congress.

The attached interim report includes data and other opinions that are still being evaluated by us to determine their relationship and significance to all of the other information that has been elicited by the Study. All of these evaluations will be reflected in the final report.

Sincerely,

Lewis M. Branscomb

Lewis M. Branscomb, *Director*
National Bureau of Standards

Enclosure

FOREWORD

This report concerns the U.S. educational system. No other sector is so nearly unanimous in its endorsement of the metric system than is education. This report examines the role that education would play, as well as the problems and opportunities it would experience, in a national change to metric.

Reports covering other substudies of the U.S. Metric Study are listed on the inside front cover. All of these, including this report, are under evaluation. Hence, they are published without prejudice to the comprehensive report on the entire U.S. Metric Study, which will be sent to the Congress by the Secretary of Commerce in August of 1971.

This report was prepared by the Education Development Center (EDC) of Newton, Massachusetts. The project at EDC was directed by Dr. Berol L. Robinson, under the general guidance of a steering committee composed of Dr. Jerrold R. Zacharias, Acting President of EDC; Kevin H. Smith, Executive Vice President of EDC; Dr. Charles Brown of the Ford Foundation; and Dr. Bobby J. Woodruff, Ridgewood, New Jersey, High School. Professor N. H. Frank of the Massachusetts Institute of Technology and Carlyle E. Maw, Jr., of Harvard University and the University of Chicago served as senior consultants to the project. Others who assisted in the project were Mrs. Cheryl Doyle, Mrs. Wendy Baron and Miss Kathleen Ennis of the Education Development Center, and Mr. Bruce D. Rothrock of the National Bureau of Standards.

In addition, many educational institutions and organizations were visited to gather data for this report, and well over a hundred persons made contributions to the work of the Education Development Center, for which it is grateful.

In this as in all aspects of the U.S. Metric Study, the program has benefited from the independent judgment and thoughtful counsel of its advisory panel and the many other organizations, groups, and committees that have participated in the Study.

Daniel V. De Simone, *Director*
U.S. Metric Study

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EXECUTIVE SUMMARY

This report is another in the series being prepared on the numerous investigations comprising the U.S. Metric Study, being carried out by the U.S. National Bureau of Standards pursuant to the U.S. Metric Study Act (Public Law 90-472). This report concerns the effects of increasing worldwide use of the metric system on education in the United States. Its purpose is to attempt

> to present the educational advantages and disadvantages of both the metric and the customary systems of units;
>
> to determine the current usage of metric measurements in schools, and trends in that usage;
>
> to find the ways in which education would have to change as the U.S. accommodates to increased worldwide use of the metric system, under a planned national program or without such a program; and to estimate the costs of the changes; and
>
> to make recommendations for ways in which to take best advantage of the changes.

We present here capsule conclusions and key them to the body of the report for support and expansion.

The chief inherent educational advantage of the customary system is its familiarity and the fact that it is embedded in a thousand years of post-Anglo-Saxon culture. Other educational advantages become apparent when the customary system is compared with the metric system—the customary units are body-related and finger-sized, while metric units are either too large or too small for very young children to handle easily. The disadvantages of the customary system are the many unrelated units, the arbitrary and various conversion factors, the need to perform longer and more complex calculations, and a nomenclature that is confusing to say the least. The chief educa-

tional advantages of the metric system lie in simplifying the teaching and learning of measurement, in relieving the educational burden of teaching two systems of measurement and in concentrating upon the simpler and more easily understood one. The only educational disadvantage of the metric system is that it is totally unfamiliar to most people and, at present, almost totally absent from the surroundings. The educational advantages and disadvantages of both the metric and customary systems of units are outlined in chapter I.

Despite the enthusiastic and long-term support of organized education, the current usage of metric measurement in elementary science and mathematics is very limited; and, indeed, measurement itself is hardly taught well at all. Increases in the use of metric units of measure are confined to the new science curricula, which now reach about 10 percent of the students in grades K-9. Forty percent of 11th graders encounter the metric system (cgs) in chemistry. This conclusion is expanded in chapter I, and supported in detail in chapter IV.

If the U.S. "goes metric," our chief educational needs will be for new instructional materials, for some training of teachers already serving, and for the replacement and modification of some instructional equipment. A minimum time scale is dictated by textbook replacement patterns; most local school districts replace textbooks on about a 5-year cycle. In addition, the publishing industry should be provided with a lead time of about 3 years for the preparation of new materials, because substantial curriculum changes will be necessary, especially to suit elementary school mathematics for the instruction of students for a metric world. If we were to have a 10-year conversion period, together with national guidance for publishers and school boards, then we should be able to replace most textbooks (and library books and encyclopedias) *at essentially no added cost* over normal operations either to local school districts or to textbook publishers. (ch. IV.A.)

In order to make the necessary curriculum changes within a scheduled conversion period, they would have to be recommended by an authoritative national body and widely accepted by both publishers and educators. This report contains a mathematics educator's recommendation for curriculum change (app. V), and a recommendation for the composition and responsibilities of a national coordinating body for education which might provide the authoritative support for the changes needed for metric conversion. (ch. V.)

We briefly summarize here the "costs" of not going metric, that is, of not having a national program of metric conversion, and the disadvantages of having too long a period of metric conversion. They differ only in degree—in either case there would be a loss or dilution of a sense of purpose and a delay in realizing the curriculum improvements which may be expected to flow from metric conversion. In a practical sense, teachers and students would continue to spend time on unnecessary drills in fractions and percent—time which would, upon metric conversion, become available for other important studies. (ch. II.)

The inservice training of about a million elementary school teachers is a major concern. Because of the relative uniformity of their preparation and

teaching tasks, a small number of exemplary training programs could serve as models for the local construction of inservice training programs for metric conversion. It is estimated that teachers should spend from 8 to 15 hours in learning the metric system and some teaching tactics: many school districts have existing inservice training programs of this extent, and in this context there would be no extra cost. In school districts which have no regular inservice training programs, it may be necessary to organize some. The rethinking of purpose and obligation which might accompany such a change should be considered a benefit of metric conversion rather than a cost.

The emphasis of inservice training for elementary school teachers should lie in the demonstration of teaching strategies and tactics. Inservice training should be strongly activity-based, because teachers teach as they are taught. A system-wide view of inservice training is given in chapter IV, together with an outline of a program for implementing it based upon the use of educational television; both are described in appendix VI, parts *a* and *b*. A recommendation for a workshop-based teacher training program to introduce the metric system and new ways of teaching and learning measurement appears in chapter IV, with further details in appendix VI, parts *c* and *d*. The implementation of the latter recommendation would lead to a "tree" of workshops. Widely used, this program for the training of the teachers might cost as much as $6 million, but it would teach not only metric units but also new ways of teaching and learning measurement.

Educational equipment is found mainly in the shops, laboratories, workrooms, and field gear of occupational education. Changes in occupational curricula and needs for equipment changes are linked to changes in the occupations themselves. We have examined about a hundred equipment lists for occupational education curricula, and we have found that the cost of modifying and replacing equipment would not be great. It amounts at most to the equivalent of a year's depreciation, which need not be taken all at once; and in many curricula the cost would be almost negligible, that is, less than a year's attrition and supplies budget.

In case there should be no national program of going metric, several recommendations can be made for the simplification of the customary system in education and in living. These include the decimal-inch proposal and an analogous decimal-pound proposal, and the increased availability of measuring devices with usable dual calibrations. The elementary mathematics curriculum reforms mentioned above and outlined in detail in the report should be implemented anyhow; but in the absence of a national purpose, they may not be realized for more than a decade, to judge by past experience. For a discussion of these recommendations, see chapter II. It has been suggested, and even resolved by national organizations, that, regardless of national action, education take the lead in promoting the metric system as *the* primary system of units in the U.S. This would be inadvisable, for we have evidence that the exclusive use of metric units in science study only can lead to a cultural isolation of science reminiscent of C. P. Snow's two cultures. (ch. IV.) On the other hand, the metric system should be given *full equality* with the customary system.

Much is to be learned from the United Kingdom's experience in education, but the forces driving metrication and the structure of education in the U.K. are significantly different from ours. There, the national inspectorate of education is very effective at the primary level and serves as a source of inservice training as well; national examinations for college and university admission are effective in controlling the secondary curriculum; and the national industrial training boards are strongly influential in occupational education. Unless we have some strong national direction, coordination, and guidance in education, the U.S. may anticipate delays and difficulties, particularly in elementary education. With the help of the test makers, secondary education will take care of itself and the problem of going metric in occupational education is largely the problem of the occupations themselves.

In conclusion, we have found that the advantages of going metric in education are significant but not overwhelming; and, on the other hand, that the costs are not prohibitive and can be met largely out of normal expenditures. A conversion period of 10 years seems to be close to the optimum, but we would need a national leadership and sense of purpose to completely benefit from metric conversion.

CHAPTER I

Introduction

The Congress has for generations heard arguments on the advantages and disadvantages of making the metric system the primary system of weights and measures in this country. The issue for the United States will soon become critical as the customary system disappears from international usage; that is, as the other English-speaking nations go metric. The United Kingdom is now in the midst of a 10-year program of conversion from the Imperial system of measurement (pints and pounds, yards and miles) to the metric system (liters, kilograms, and meters): their national program is proceeding under the coordination of a widely representative Metrication Board at the same time that the decimalization of coinage is proceeding under the guidance of a Decimalization Board.[1] India undertook in 1956, in the political climate of independence and with the support of Nehru, the double task of going over to a decimal coinage and the metric system of measurement. Many other members of the British Commonwealth of nations have made commitments to change to the metric system.

The Secretary of Commerce has been directed by the Congress (Public Law 90-472, 8 August 1968) to report to them on the impact of this increasing worldwide usage of the metric system on the United States. The National Bureau of Standards has been assigned the task of carrying out a study of the questions raised by the Congress and of preparing a report.

The U.S. Metric Study has been developed by the National Bureau of Standards in the form of 14 components, which are described in the first

[1] On 15 February 1971, the United Kingdom officially converted to a decimal coinage with the introduction of ½, 1, and 2 new pence coins. A month later it was described as the "non-event of the century."

U.S. Metric Study Report, "International Standards."[2] It includes a number of surveys and investigations of a wide range of topics and a series of conferences, including a conference on education.[3] Perhaps the most important single contribution to the Education Conference was the comprehensive position paper of the National Education Association (NEA). It covers the history of the support of organized education for the metric system, and summarizes usage, educational advantages, adjustments to be expected, and costs; and offers a tentative schedule for going metric. This paper is reprinted as appendix II of this report.

Another valuable contribution was the report of the National Science Teachers Association (NSTA) to the Education Conference. It addresses itself to the questions of classroom activities and instruction, possible future effects of going metric, and submits the official position of the Association on this issue and the opinion of its leaders. This report appears as appendix III.

Education Development Center (EDC) was asked to undertake a study of the effects of going metric upon education in the U.S., and to determine:

(1) The current usage of the metric system and trends in its usage, and the advantages and disadvantages of current practice.
(2) The consequences of increased international usage in the event that no national program is undertaken.
(3) The problems which would have to be faced in implementing a positive national policy and program over a 10-year period of conversion or over some "optimum" period.

EDC was asked also to develop recommendations and guidelines for minimizing the difficulties of the transition and for best realizing the long-term benefits.

In the course of this Study it has become clear that in the area of education there will be difficulties associated with the transition but they would not be great. On the other hand, it seems clear that the advantages to be gained are significant but not overwhelming. The major problems to be faced in education are the replacement of textbooks and other instructional materials, the modification or replacement of equipment, and teacher training (quite aside from a national THINK METRIC campaign, see ch. VI). The chief subsidiary advantage to be gained, aside from the simplification of teaching and learning measurement, appears to lie in the opportunity to make curriculum reforms, particularly in elementary mathematics.

The task of the Education Development Center is to assay the extent of the problems and implications of a change to SI units,[4] and to develop the information upon which guidelines and recommendations can be based.

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[2] National Bureau of Standards Special Publication 345-1, Washington, D.C., (December 1970); pp. 43-45. Hereafter we shall refer to this report as "International Standards."

[3] Held at the National Bureau of Standards, Gaithersburg, Maryland, 14 and 15 October 1970. Hereafter we shall refer to this Conference as "the Education Conference." The program is included as app. I.

[4] A glossary will be found on p. 198.

Summary of Current Usage and Trends in Use

Organized education has long been enthusiastic about the metric system, and they have been on record in favor of it for many generations. With the introduction of the metric system they have seen essential simplifications of teaching and learning tasks.[5] At this time, in a planned period of going metric, they see, in addition, a chance for another round of curriculum reform.

However, the current usage of the metric system in education in the United States is limited, and students do not learn to think metric because they are living in a totally nonmetric environment. Only about 10 percent of elementary and intermediate school students are exposed to the new science curricula in which metric units of measure are used in substantial amounts. The trend toward increase in the usage of the metric system is small but noticeable; it appears mainly in the new science curriculum developments, but the commitment of these new science curricula to metric measurement appears to be at the peril of introducing a language barrier between science and the real world. In contrast, conventional science texts for the elementary and intermediate grades do not use significant amounts of metric measurement, nor is there promise of any appreciable increase.

At all levels of mathematics instruction, the metric system has a low priority. In the typical elementary mathematics curriculum, little time is spent on measurement, and of that, at most 20 percent is spent on the metric system. When the metric system is introduced, it is taught as a second measurement language, and students learn it by translation with no chance to develop an instinctive use.[6] In high school, the teaching of measurement is not a mathematics topic, and it is left to the science courses.

The metric system is used to an appreciable extent only in the chemistry and physics courses taught in high school and college. Small increases in metric usage are noticeable in high school physics, but so long as engineering colleges expect their students to learn about pounds force and pounds mass and Btu's, many college physics teachers will feel obliged to teach in those units. Chemistry is completely metric (cgs) and has for generations reflected the practice of that profession.

Conclusion: Despite the enthusiastic support of organized education, the current usage of metric measurement in elementary science and mathematics is very limited. Its increase is confined to the new science curricula which now reach about 10 percent of the students in grades K-9. Forty percent of 11th graders see the metric system (cgs mainly) in chemistry.

In the classrooms, laboratories, and workshops of occupational education, both the instruction and usage of measurement are tightly linked to the practices of the occupations for which they train. Leaders in occupational educa-

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[5] See app. II, for a history of the National Education Association's support from 1870 to 1970, and app. III for the National Science Teachers Association's statement.

[6] National Council of Teachers of Mathematics, presentation at the Education Conference.

tion generally are not in favor of having education take the lead in metric conversion until there is evidence that the country as a whole is converting. In each occupation, there will be a reluctance to teach metric units of measurement until it is clear that that occupation is about to go metric. When the time comes to introduce metric units into an occupational curriculum, a transition period will be needed during which both metric and English systems will be used in the schools. Occupational educators feel that such a bilingual stage and a coordinated and orderly transition would neither produce confusion nor require expensive alterations in present instructional equipment.

Educational Advantages and Disadvantages of the Customary and Metric Systems of Measurement

The chief educational advantage of the customary system of measurements is that it is familiar. Its other advantages are seldom recognized—the units are body-related and finger-sized. Young fingers can easily manipulate one-inch tiles and cubes and ounce weights, but millimeters, centimeters, grams and cubic centimeters are just too small and the kilogram is too large.[7] Young minds have difficulty in comprehending numbers as large as 300.[8] And in general there is a loss associated with the rejection of the measurement-related parts of a thousand years of post-Anglo-Saxon culture, as epitomized in the last verse of Robert Frost's famous "Stopping by Woods on a Snowy Evening"—

> The woods are lovely, dark and deep.
> But I have promises to keep,
> And miles to go before I sleep,
> And miles to go before I sleep.

The disadvantages of the customary system are that there are many unrelated units, that the conversion factors from unit to unit are arbitrary and various, that the same names are used for different units (for example, dry and liquid quarts, ounces of weight and capacity), and that similar units have entirely different names (for example, minim, dram, ounce, gill, [cup[9]], pint, quart, [pottle[10]], and gallon). The present style of measurement is to work mainly with common fractions and mixed numbers, so that computations are complex and lengthy.

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[7] School experience in the UK has led to preferences for 5- and 10-gram plastic weights and larger-than-centimeter blocks and tiles.

[8] 300 mm = 1 foot. In education at least, the "nonpreferred" centimeter must be used as a unit of length.

[9] A cupful is half a pint—a kitchen measure but not a legal one.

[10] "two quarts make a pottle; two pottles make a gallon." *A Dictionary of English Weights and Measures from Anglo-Saxon Times to the Nineteenth Century*, R. E. Zupko, University of Wisconsin Press, Madison (1968), p. 132.

The chief educational advantage of using the metric system lies in the simplification of teaching and learning how to measure. This advantage arises from the simple interrelations of units mainly based on multiplication by 10, and from the ease of computing with decimal fractions and whole numbers. An obvious educational advantage would be that the educational system would no longer be burdened with teaching two systems of measurement, and would be able to concentrate on the one which is simpler and more easily understood. Time saved due to teaching a simpler system could be used for the introduction of valuable new materials. Another advantage of metric usage is that the teaching of decimal fractions, now much delayed, *must* occur earlier. (It is remarkable that the first nation to adopt a decimal coinage should after 180 years still not teach decimal fractions in the *early* elementary years.) At the same time, much of the customary drill in fractions could be reduced, although we should of course retain an easy familiarity with halves, thirds, quarters, and fifths (and perhaps sixths and eighths).

The only disadvantage of teaching the metric system is that it is totally unfamiliar to most people, and metric measurement is almost totally absent from the surroundings at present. In spite of the fact that the U.S. has a decimal coinage, its decimal-fraction nature is not related to measurement: decimal fractions are used only in very special contexts. For example, machine shop practice uses the decimal inch notation, and surveyors measure to the nearest hundredth of a foot. More commonly, gasoline is measured in tenths of gallons (but nobody ever notices because the computing pump permits you to buy by the dollar's worth or by the "fill'erup").

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CHAPTER II

Bilingualism in Measurement Language

The rest of the world is or soon will be metric. Those countries that have decided upon a course of metric conversion are not likely to reverse it, regardless of an action by the U.S., and indeed the U.S. Metric Study has excluded from its consideration the possibility that the U.S. could arrange

> some mandated action to *reverse the trend* toward metrication in favor of a return to more complete use of "customary" hardware and software.[1]

Therefore, it should be recognized that there will be an increase in bilingualism in measurement language whether the U.S. goes metric or not.

In case there is a national program of metric conversion, the increase will be a steady and coordinated one, in which all will be involved over a short period of time. If there is no national program, the most obvious impact of the increasing international use of SI will be the obligation of students and teachers at all levels (and indeed for others in all walks of life who are involved with any sort of measurement) to deal increasingly and over a long period of time with a real world in which two measurement languages are used. One may expect the increase in bilingualism to be slow and sporadic, with larger steps as major industries convert. This course is regarded by some as the natural way in which metric conversion is bound to come about. They say that to interfere with that slow process would be too great a shock, especially for industry. One might ask such people whether they would take language lessons if they were obliged to go to live in another country, or just

[1] "International Standards," p. 42.

limp along with whatever they could pick up in the course of their stay, or indeed behave like the caricature of the Englishman abroad, who feels that anyone can understand English if only it is shouted loudly enough.

The "Costs" of Not Going Metric and Recommendations

Bilinguality would be an inconvenience and a source of confusion and some small expense, but the real "cost" in education of not going metric on a coordinated national time scale must be expressed in terms of benefits foregone. Perhaps the most significant is the delay in realizing the next stage in the reform of the mathematics curriculum in the elementary grades. At present an inordinate amount of time is devoted to common fractions and percent problems, while the study of decimal fractions and place value is much delayed. The inertia which preserves such practices can be overcome by a national program of change, but it seems likely that little innovation will occur otherwise. The loss of time is quantitatively estimated at a year to a year-and-a-half in grades 1-8;[2] that is, about 15 percent of the instruction time in mathematics is absorbed by drill in fractions and percent, time which might otherwise be devoted to the introduction of important new materials.[3]

Second only to elementary mathematics is the cost in time and learning effort for science students and teachers, of learning and teaching the metric system as a second measurement language. Both students and teachers have virtually no use for metric measurement outside their science classes, and emphasis on the metric system in science alone tends to create a language barrier between science and the rest of the world of learning and living. This would continue until the balance is tipped in favor of metric units.

Furthermore, it is widely believed that measurement concepts and operations are hard to teach and are ill-taught at present, in a milieu of one overwhelmingly predominant measurement language. One may reasonably expect these difficulties to increase as a second language comes more into use in the U.S., and to continue until the metric conversion becomes more or less complete.

In case there should be no national program for going metric, several *recommendations* can be made for the simplification of the customary system of weights and measures in education and in the "real world." The use of binary fractions of inches should be discouraged in favor of decimal

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[2] See app. II, and app. V.

[3] One is tempted to make an estimate of the dollar value of the time involved. We note that elementary and secondary education costs about $40 billion per year (app. IV), of which almost 70 percent is directly attributed to the cost of instruction (Digest, p. 53). Thus we may compute the cost of instruction for grades 1-8: it is about two-thirds of 70 percent of $40 billion, or about $18 billion per year. Let us now suppose that 20 percent of the curriculum is mathematics, and we have just said that about 15 percent of that time is wasted because we don't use the metric system. Now 15 percent of 20 percent of $18 billion is about $500 million; so, in these terms, the costs of not going metric is the continuation of this $500 million waste of time each year.

fractions,[4] and whole-inch measure should be encouraged in place of foot-inch measure.[5] Rulers and tape measures should be inscribed in both inches and centimeters in parallel and not anti-parallel as is the custom with present day school rulers (fig. 1). The use of decimal fractions of a pound should be encouraged in retail trade. Decimal fractions should be introduced earlier in the arithmetic curriculum, and the extensive drill in common fractions, which occupies so much of elementary arithmetic, should be much reduced. In fact all the recommendations of this report for elementary mathematics curriculum reform are valid and should be implemented whether there is a metric conversion or not: those related to measurement and the early teaching of decimal fractions must necessarily accompany a metric conversion. Finally, the education sector should encourage the trend toward increasing use of SI in the U.S. by giving it *full equality* with the customary measurement language in the elementary grades.

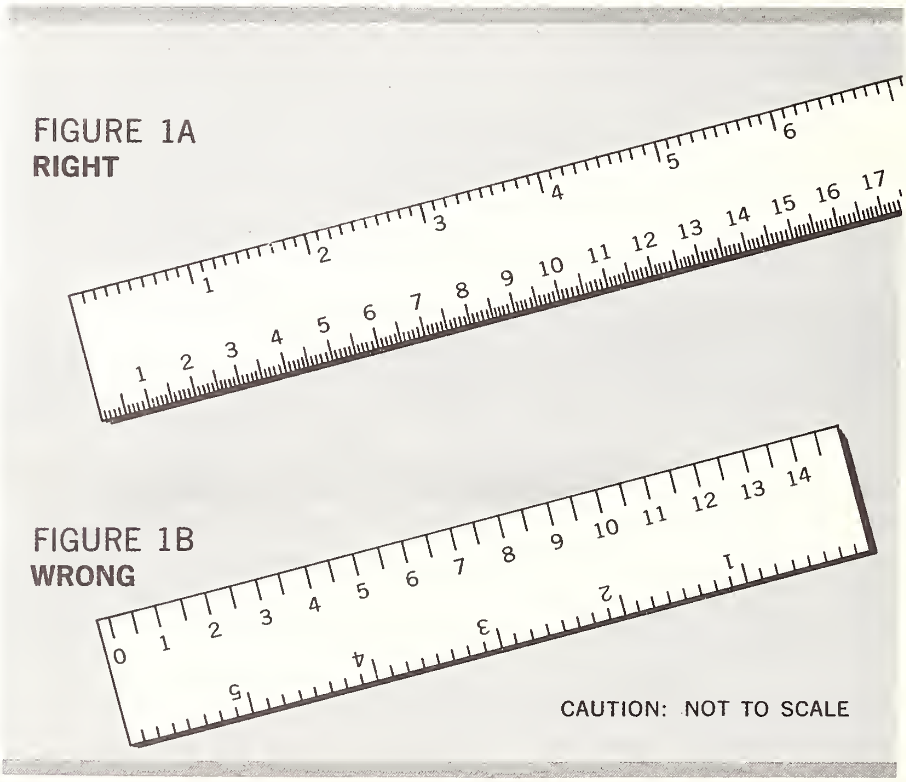

FIGURE 1A. Inch-centimeter ruler ruled in parallel

FIGURE 1B. Inch-centimeter ruler ruled in anti-parallel

[4] P. G. Belitsos in *Systems of Units*, AAAS Symposium, 29-30 December 1958, Carl F. Kayan, ed., Publication No. 57 of the American Association for the Advancement of Science, Washington, D.C. (1959), pages 203-216. (We shall henceforth refer to this symposium report simply as "*Systems*.")

[5] In whole-inch measure a distance of 4 feet 8½ inches would be written 54.5 inches. One would convert to this figure before calculating with this measured quantity: it seems logical to measure it directly and thus save time and eliminate the possibility of an error in conversion.

Recommendation: In case there should be no national program of going metric, several recommendations can be made for the simplification of the customary system in education and in living. These include the decimal-inch proposal and an analogous decimal-pound proposal, and the availability of measuring devices with dual calibrations. The elementary mathematics curriculum reforms outlined here should be implemented anyhow, but in the absence of a national purpose it may take decades to get it done.

Costs and Benefits of Going Metric and Recommendations

It is easy to make very rough estimates of the dollar costs of going metric in the education sector, but precise data are very hard to secure because of the diversity of education in the U.S. We shall make a rough estimate of the cost of "instantaneous" metric conversion, and we shall find that even such an event would not be prohibitively expensive. We shall then demonstrate that these costs can be driven nearly to zero by an orderly and planned national program of conversion over a period of about 10 years. In view of these results, it seems hardly worth the effort to secure the data to support more precise calculations of either cost.

Finally, we have indicated above that there are disadvantages and losses, if not dollar costs, associated with a long drawn-out conversion.

On the other hand, it must be pointed out that the benefits cannot by any stretch of the imagination be given a dollar value. This contrast is in part due to the fact that the costly items can be readily enumerated, even if they cannot be evaluated; while the educational benefits can be described only in a relative way: "the metric system is easier to learn and understand and manipulate," and in terms of new opportunities: "the time that would be saved in teaching and learning certain concepts and skills can be devoted to other important concepts and skills."

As in all other aspects of going metric, the costs are one-time costs, while the benefits are cumulative in time, so that their total worth increases indefinitely as time goes on. In short, one is comparing a one-time cost with a continuing benefit.

It is the experience of the U.K. Metrication Board that the costs and benefits of metrication in industrial operations are intimately mixed with the costs and benefits of other changes, for the change to new measurement units typically affords the opportunity to reassess an entire operation. In industry, only the most sophisticated accounting procedures would be able to distinguish one cost from another, and it seems hardly worthwhile to do so;[6] the same may be expected in education.

In education, curriculum, materials, and methods can be looked at in a fresh and critical light. In particular, we shall have the opportunity for

[6] Gordon Bowen, "Going Metric in the United Kingdom," a talk before the General Conference of the National Metric Study Conferences, 16 November 1970.

another round of curriculum reform, especially in science and elementary mathematics. It is in such opportunities that the greatest gains of going metric can be realized in education, but they will not flow spontaneously—we shall have to work and plan for them.

Benefits that would be a direct consequence of metric conversion are: the obvious educational advantages of the metric system, that is, the simplification of units with consequent reduction of complex calculations, and the ease in teaching and learning measurement, as outlined above, and the recovery of a large block of teaching time currently spent on fractions and percent. Certain long-overdue curriculum changes, such as the teaching of decimal fractions in grades 2 and 3, must accompany a metric conversion. This and other changes should be undertaken regardless of whether we go metric, but they will be a long time coming without the national sense of purpose and atmosphere of change.

Before we proceed to make some dollar estimates, let us point out that the United States is spending about \$70 billion on its formal education establishment in the 1970-71 school year.[7] In this setting, let us make a few simple manipulations.

Instructional materials include textbooks, library books and reference materials, and nonprint materials, such as audiovisual aids and manipulative materials. Textbooks are by far the major fraction of this category. Let us consider the replacement of textbooks, for this would seem to be a relatively simple computation to make. There are about 50 million students in our primary and secondary schools, most of whom are furnished textbooks at public expense. Suppose that going metric would require the "instantaneous" replacement of four textbooks for each student (mathematics, science, social studies, and one other), and suppose that each book costs \$5 (these figures are deliberately chosen to be on the high side, among other reasons to include the cost of "instantaneous" curriculum revision). The total "instantaneous" replacement cost appears to be about a billion dollars:[8]

$$\begin{matrix}\text{50 million}\\ \text{students}\end{matrix} \times \frac{\text{4 textbooks}}{\text{student}} \times \frac{\$5}{\text{textbook}} = \$1\ \text{billion.}$$

But most textbooks are replaced regularly with new editions after 4 to 6 years of use. Indeed, the continuing expenses for textbooks, library books and other library materials, and other instructional materials are estimated

[7] The \$70 billion education budget for this year includes about \$40 billion for primary and secondary education, about \$21 billion for post-secondary education, and about \$9 billion for capital expenditures. (app. IV.)

Education has grown from about 5.4 percent of the Gross National Product in 1960 to about 7 percent in 1970. (Digest, pp. 17, 18.)

App. IV is a brief summary of education statistics. Some other sources of general statistical information used in the Report are listed in the Bibliography.

[8] To make this astronomical number more tangible, let us reduce it to a per-student cost. The average cost of primary and secondary schooling comes out to be about \$800 per student per year, (see app. IV) of which \$40 (5%) is spent on books and other materials. In comparison to this annual cost, we have estimated that the one-time cost of textbooks suitable for instruction in a metric world is about \$20 per student.

at 5 percent of the total expenditures for primary and secondary education,[9] which are now running at the rate of $40 billion dollars per year. Thus we now spend about $2 billion dollars per year for instructional materials. If the replacement of textbooks for going metric were spread over a period of 3 to 5 years, then the cost would be easily absorbed in the usual replacement process. If in addition editors and publishers were given a lead time to prepare new materials, then the cost of curriculum revision would be minimized and unit prices not increased.

Too long a conversion period or a long drawn out drift toward metric conversion might dilute or sacrifice the sense of purpose and change and it would of course continue the need to teach two measurement languages, and delay the curriculum changes which we believe would save much time and effort in elementary mathematics.

Conclusion: Considering textbook replacement alone, it is clear that a 5-year period of metric conversion borders on being too short, and that a 10-year period would be easily accommodated. A 10-year period might include a lead time of 2 or 3 years for the preparation of new curriculum materials.

Textbook replacement is a good example of the way in which the costs of conversion become inseparable from the opportunities that conversion might bring. The need for completely new textbooks and for the earlier introduction of decimal fractions in elementary mathematics affords us a new chance to revise that curriculum.[10] One cannot distribute the cost of such progress between going metric and the curriculum reform undertaken at this time.

The costs for replacing and modifying instructional equipment are more concrete, since much instructional equipment has a longer lifetime than any proposed period for metric conversion. This is particularly true of the equipment which is used in the shops, kitchens, laboratories, and workrooms of occupational education. These costs can, in principle, be computed by determining the cost for each kind of shop and multiplying the figure by the number of shops. (This subject is discussed in some detail in ch. IV. C.) We have come, after considerable investigation, to the conclusion that short of a door-to-door census, no more than the roughest approximation can be made for the cost of metric conversion. There is a wide variety of equipment in shops of any given type, and the classification of shops is in itself a problem. Furthermore, one must take into account not only the shops of existing programs but also those programs that would be started in a period of metric conversion. In light of the growth and development of the entire field of occupational education, presently available data and the trends of the recent past are of relatively little use in making predictions in this field for the next decade or two. Recent legislation[11] is already encouraging changes in present

[9] National Education Association Research Division, "Cost of conversion to the metric system," (September 1970).

[10] A detailed recommendation on curriculum changes for school mathematics has been obtained and appears in app. V of this report.

[11] Principally the Vocational Education Act of 1963, Amendments of 1968, and the Higher Education Facilities Act of 1963.

patterns of occupational education, and pending and proposed legislation may be expected to produce still more changes. Meanwhile, our nation is getting new perspectives on its manpower needs and on the ways in which formal schooling can satisfy them.

In general, occupational education practices are closely linked, on a one-to-one basis, with the practices of the occupations for which the students are prepared. The educational benefits of going metric are not much greater than the benefits would be for the occupations and industries involved. In addition, much more is learned in occupational education than how to measure, and the value of that learning is not particularly dependent upon a measurement system. Many occupational educators say there would be no great pressure to replace or modify equipment, and others look forward to earlier retirement of existing equipment. Nevertheless, care and planning will be required in each occupational education program to achieve a metric conversion at minimal cost in parallel with the conversion of occupational practices.

Using various models, calculations can be made of the costs of the teacher retraining that would be required by going metric, either "instantaneously" or in a planned way. We shall show that in a planned and orderly metric conversion, this cost could be largely but perhaps not totally absorbed in existing programs of inservice training, since many teachers already participate in regular programs of various kinds. The current status and problems of inservice teacher training are discussed in chapter IVB; and a general view of the problem and detailed proposals for inservice training appear in appendix VI.

CHAPTER III — SOME GENERAL CONSIDERATIONS

Methods

The education component of the Metric Study was carried out through a campaign of visits, interviews, and telephone conversations with a wide variety of people in education. Some were identified to us as experts in their respective fields by the steering committee and by the senior consultants, and others hold positions of responsibility in national organizations. The Education Conference of the National Metric Study provided a number of contacts and a wealth of authoritative information; and a small conference of occupational educators was held to validate progress on that issue. This method does not provide statistically valid data in the classical sense, but one may expect to secure representative information which, by the agreement of various subjects with each other and by the agreement of subjects with different views of the same question, will permit conclusions to be drawn and recommendations to be developed. For example, both the editors of textbook publishing concerns and the state officers who are responsible for selecting and purchasing large numbers of textbooks in some state education departments agree that no serious difficulties should be expected in providing adequate metric texts and in getting them into the classrooms in accordance with any reasonable schedule of going metric. Indeed, both agree that very little is likely to be done unless there is an organized and coordinated national program of metric conversion or some evidence of national direction on the part of the national educational leadership if no such program should be undertaken.

Our interviews have been with publishers, suppliers of other educational materials, officers of state education agencies and city school departments, curriculum development people (including those charged with the prolifera-

tion of new materials), supervisors, principals, and teachers. In various parts of the country we have visited elementary and secondary schools, vocational and technical schools, centers for the development of new materials, and centers of leadership and coordination in the proliferation of new curricula. Toward the end of the study a visit was made to the United Kingdom to observe British experience with metrication in education which was just begun this year on a large scale after several years of preliminary thought and preparation.

We have examined conventional and innovative instructional materials in the subjects which may be expected to be most affected by our going metric, in order to determine the extent of the changes needed in them. In addition, we have secured expert advice concerning the extent of curriculum modifications, particularly in elementary mathematics, which ought to accompany or follow shortly upon any metric conversion.

For a variety of reasons, the education component was not undertaken via a system of questionnaires, as were several other components of the U.S. Metric Study. An important factor was the time constraint: it seemed unrealistic to consider the mounting of a field-tested and Office-of-Management-and-Budget-approved questionnaire in the limited time available. An equally important concern was the impracticality of preparing a single questionnaire that would be adequate for the variety of issues which confronted this Study and for the variegated audience we expected to seek out. Finally, we decided that a mailed questionnaire would be likely to get only a meager response from an overworked audience which might well view the matter as a relatively frivolous one in comparison to the other issues which face education today.

Metrication in Education in the United Kingdom

The U.S. Metric Study has been carried out in an atmosphere so different from that in which the United Kingdom approached metrication that many of the lessons learned there are not applicable to the problems of the United States. In the U.K., the manufacturing industries came to the national government with a proposal embodying the need which they perceived for going metric soon. Under the pressure of foreign trade with metric countries, they asked the government to adopt their plan as a national program and to provide the coordination necessary to see it through. Such a proposal is not likely to arise from U.S. industry, and the reason can be clearly seen in the relative unimportance of foreign trade in the U.S. as compared to the U.K.

In the U.K., nearly 20 percent of the gross national product lies in export trade, while in the U.S. it is only 4 percent (and over a fifth of that is export to Canada). The difference is amplified by the character of the exports (the U.S. exports relatively more in the way of bulk-measured commodities: chemicals, crude materials, food and live animals), by the negative balance of trade in the U.K. (imports exceed exports), by the geographical

closeness to the continent, by the conviction that the U.K. must in the end be admitted to the Common Market, and by the need and intention of the U.K. to find trading partners in Eastern Europe and on the China mainland, all metric countries. In these circumstances, industry is leading, and education can afford to follow; as it did with a time lag of some 2 1/2 years between the Government's commitment to the metric system as the primary system of weights and measures and the beginning of activity in education with conferences called by the Royal Society.

By contrast, most firms questioned in the Manufacturing Industry Survey of the U.S. Metric Study stated that increased metric usage is in the national interest; yet very few are prepared to expose themselves to competitive disadvantage by stepping out in the lead of their industry. Indeed, in the absence of a national program it might be unwise for them to do so, although the pharmaceutical industry stands as a counter-example.[1] In addition, some American industries tend to react to competitive imports by restricting foreign trade, as exemplified by the proceedings of the 91st Congress in which a major tariff war was only narrowly averted (if indeed it has not merely been postponed). In this situation, it seems clear that education could play a much different role; and if a nationally coordinated program of going metric were to be undertaken in the U.S., then it would be appropriate for education to lead.

The "political" differences outlined above, including the potential availability of a lead for education to prepare for conversion, and the structural differences between education in the U.K. and the U.S. to be described below, tell us clearly that we shall have to do things differently in the U.S. Yet the careful thought given to educational problems of metrication in the U.K. can provide significant guidance.

In general, education in the U.K. is much more uniform and nationally controlled than in the U.S., but with considerable local freedom in administration and especially in the individual schools and classrooms. Coordination is provided by a number of national official agencies. The national inspectorate of education is very effective at the primary level; national examinations for college and university admission are effective in controlling the secondary curriculum; and the City and Guilds of London Institute and joint committees for national certificates and diplomas have long been influential in occupational education. There is little in the U.S. that can be said to be analogous to these national bodies. Unless we have some strong national direction, coordination, and guidance in going metric in education, the U.S. may anticipate delays and difficulties. A recommendation appears below, chapter V, for the appointment of a national coordinating body, suggesting its constitution, and outlining its responsibilities.

A brief bibliography, mainly consisting of pamphlets produced in the U.K. for widespread distribution there, appears on page 200. It is important to note the range of interest of the pamphlets and the variety of originating agencies.

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[1] R. W. Ernsberger in *Systems*, pp. 249-258.

Occupational Education

Early in this study, we found that certain parts of the broad spectrum of occupational education would be sensitive to metric conversion, and we have, therefore, concerned ourselves quite extensively with occupational education.[2]

The major fraction, by far, of the educational equipment to be replaced or modified on account of metric conversion is found in the shops, laboratories, workrooms, kitchens, and field equipment of the occupational education programs. The students engaged in occupational studies are a large fraction of those who will go out into the world of work to make real measurements on real objects. These students also will work during the (extended) period of transition beside older workers who will retain patterns of thought and work habits based on the customary system of units. Instructional materials in occupational education are also very diverse, and the qualification of teachers is quite different from that of academic teachers. For these reasons, we have paid special attention to this part of education.

Occupational education covers several hundred different fields of work, and each curriculum is tightly linked in its practices to the occupation for which it trains. The practices of those occupations are not the concern of this Study, except that they would be reflected in education in the cost of equipment modification and replacement. However, new occupational practices may give rise to new ways of teaching and learning which would in turn be reflected in teaching materials and teacher qualifications, and we should be alert to these subsidiary effects.

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[2] In defining "occupational education," one must first distinguish among the various levels of education and useful skills that a student might be helped to develop. One facet of education is its concern with the development of the individual as a cultured and educated person, while another deals with preparing him to function as a contributing member of society. In a general and unfocused education, teachers hope to teach and students to learn the fundamental cognitive and manipulative skills basic to any civilized enterprise. Broadly, these include communication and language, the use of numbers, a sense of the history of mankind, an understanding of the natural world in which human life is embedded, and an appreciation for the structure of human relationships and organizations.

In finer focus, but still quite blurred, education pays some attention to the preparation of the individual for a number of vocations, occupations, and professions, without foreclosing the options among them. For example, a health sciences program should prepare students in a quite general way for further specialization in the health career ladder, which may run from ward management to X-ray technician to nurse to physician to medical scientist. Other broad categories of this type would include the law, government service, and the mechanical and energy-related occupations.

A sharply focused curriculum prepares its students for specific work with a breadth of skills and knowledge which is successively greater as one progresses from manpower training (teaching mainly current skills) to occupational education (skills and a base of knowledge and understanding upon which to broaden them), to professional education (broad and deep enough to support independent work and the development of new enterprises). It is this definition of occupational education at a secondary and post-secondary school level that we use here.

CHAPTER IV — PRESENT STATUS AND PROBLEMS OF TRANSITION

In this chapter, we shall present our findings on the present use of metric measurement in instructional materials, on the patterns of teacher qualification and retraining, on the use of equipment particularly in occupational education, and on several other concerns of education. In addition, for each category we shall outline the problems that would have to be faced in metric conversion.

A. Curriculum, Materials, and Testing

TEXTBOOKS

Publishing and Purchasing Patterns

Conversations and interviews with editors have revealed that very few difficulties may be expected in the revision of textbooks, workbooks, and teachers' guides. In order to meet the requirements of state and large-city school systems which approve or adopt and purchase textbooks on a statewide or system-wide basis, most publishers revise their elementary and secondary texts every 3 or 4 years. In order to qualify for copyright as "revised" rather than as a "new printing with corrections," a book must have changes on at least 20 percent of its pages. Many of these "copyright revisions" or "adoption revisions" in the textbook industry are made with the further limitation that there be no change in the page numbering of the

unrevised pages.[1] Thus many metric revisions could be accommodated within the scope of existing revision patterns.

The adopting agencies may have a different view of the time scale. Perhaps an extreme case is the state of California: up to 4 years may elapse between the appointment of a state-wide committee to design a "framework" or course of study for a given subject for grades K-8 and the appearance of the new texts in the classrooms of the state. During that time the framework is written and approved, criteria are established for judging the submitted textbooks against the course of study, bids are invited, contracts are let, the books are printed in the state printing office and distributed to the schools, and teachers may be trained in the use of the new curriculum. On this account, it would take a longer time to get metric textbooks into the hands of California school children if the phasing turned out to be just wrong.

Among others, we spoke about the problems of educational publishing to Dr. James R. Squire, the chairman of the research committee of the school division of the Association of American Publishers, the book publishers' trade organization. Dr. Squire discussed the matter with his committee and in describing their views of the problems they would face in going metric, he wrote:

> No one anticipates that major problems for educational publishing will result if this change accrues over an extended period—say, 10 years as in the United Kingdom. The normal revision cycle and pattern of new introductions for school and teacher education programs will almost ensure adequate attention to the metric system in schools and colleges. Indeed, an increase in attention to metrics is apparent in many school programs currently in preparation, and a large number of college books already are based on the metric system.
>
> Individuals assume, of course, that we shall see instruction in dual systems for many years. They note further that even if 10 years is allowed for conversion, some school districts may require financial support to purchase new instructional materials at the end of the period. Despite the estimated 5-year average adoption cycle, a number of districts cannot, or will not, purchase new books. Even today, despite a decade of new mathematics, we know of schools using mathematics programs published during the 1950's.

The impact of going metric upon textbook replacement may be lessened somewhat by the trend away from the adoption and use of hard-covered textbooks and textbook series. States which once required textbooks to be

[1] We have examined two popular and widely adopted sequences for science for grades 1 through 6, including the series adopted by the State of California and provided by the State to all students. We discovered that all use of foot-pound-gallon measure can be converted to meter-kilogram-liter measure well within the above 20 percent limitation for the series. Other desirable revisions which should immediately accompany a change of units (such as the increased and earlier use of decimal fractions, powers-of-ten notation, approximate calculations, and new treatments of weight and mass) will not increase, to any significant degree, the number of pages to be revised. These textbooks are described in more detail in the following section.

used "as the principal medium of instruction" now permit the use of such nontext courses of study as the American Association for the Advancement of Science's "Science—A Process Approach," which is based mainly upon kits of manipulative materials and a teacher's guide. Some school systems are quite dissatisfied with monolithic textbook series and design their curricula around paperbound booklets to a considerable extent.

Conclusion: In the course of normal reprinting and revision practice, many textbooks could undergo metric conversion in a period of 5 years or less. If a lead time of 2 or 3 years were provided for editorial changes, and if the people who select and buy textbooks were advised that changes were in process, and if they adjusted their replacement and renewal schedules accordingly, then new materials would reach students promptly after the beginning of a metric conversion period.

Publishers and school officials have expressed their opinions to us that supplementary metric pamphlets on metric usage or units on the metric system might be used together with the texts already in their schools, or that such materials could be adopted together with revised texts for an interim period. Such an approach must be made with extreme caution. In a textbook series with very little measurement and very few "classroom-laboratory" instructions, it may be adequate; however, it appears to us that many textbook sequences ought not to be patched up that way, and in particular, that the revisions and reordering of subject matter called for in the elementary mathematics curriculum are so extensive that such an approach would fail completely, as we shall show in the next section.

Finally, it is our view, which we shall expound in some detail in dealing below with inservice training of teachers, page 45 and appendix VI-c, page 121, that teaching and learning metric units must be combined with better ways of teaching and learning measurement, and that these must be strongly based in activities. This conviction is based in part upon the experience of curriculum innovation projects which use exclusively the metric system in laboratory work. They have found that it is best if students and teachers alike learn to use metric units by measuring familiar things in metric units only and, by this total immersion method, develop a familiarity with their use. In particular, they warn against any attempt to teach metric equivalents and conversion from English to metric units.

Elementary Mathematics

In examining elementary mathematics texts, we looked for ways in which metric measurement is introduced and tried to see how these texts might have to be revised to serve the needs of a metric world. We carefully examined one of the more popular elementary mathematics sequences,[2] and believe it is fairly typical of the better elementary mathematics curricula. We found rather little mention of metric units, and that was primarily in tables of

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[2] *Modern School Mathematics—Structure and Use,* Duncan *et al.*, Houghton Mifflin Company, Boston (1967).

conversion factors given in slightly different form each year and followed on each occasion by a page of conversion or other manipulative exercises.

The metric system is introduced for the first time in the 3d grade:

> In many countries another unit of length is used. It is a little smaller than half an inch. It is called a *centimeter.*

This is followed by two exercises in measuring line lengths with a centimeter scale, constructed by the student himself, and a few more measurements in the next lesson. All this accompanies similar exercises with an inch ruler.

Decimal fractions with one figure after the decimal point (tenths) are introduced in the 4th grade, two figures (hundredths) at the end of the 5th grade, and three figures (thousandths) at the end of the 6th grade.

Although money is introduced at the end of the 2d grade and at the beginning of the 3d, no attempt is made to introduce a decimal notation there. The students learn that two green oblongs, a quarter "worth 25 cents," and two pennies have a total worth of 227 cents. Toward the end of the 3d grade the "separating point" is introduced as a notational device to separate dollars and cents, and the teacher's guide has the warning:

> It should be referred to simply as "the point." Later, in working with fractions in decimal form, the students will use the point in a different way. At that stage the decimal point introduces tenths, hundredths, and so on.

A considerable amount of work is devoted to common fractions—they are introduced early as fractions of areas and of sets, and then each year there are exercises in addition and other manipulations. In grade 7, the students learn the four arithmetic operations on fractions together with the conversion of decimals and fractions, and ratio, proportion, and percent; and in grade 8, the four arithmetic operations on decimal fractions.

By the 6th grade we find:

> The most widely used system of measures in the world is the metric system. This system has the advantage that it has a base of 10 like *our* system of numeration. (emphasis added)

This is followed by a table of approximate equivalents ("one centimeter is about 2/5 inch") and half a page of exercises on approximate conversions.

In the 8th grade, there is a unit on the metric system sandwiched between a unit on exponents and "scientific" (power-of-10) notation and one on the arithmetic of decimal fractions. The chapter entitled "The Metric System" presents in a tabular form all units of measure, both metric and English, and the conversion factors for length and area, capacity and volume, and weight and mass. It then offers many exercises in converting from one system to the other: English to metric, metric to English, metric to metric. The prototype question is "How many – – –s are there in a– – – ?"

Pattern and Structures,[3] another of the elementary mathematics sequences we examined, is a series of eight textbooks designed for a basic 8-

[3] *Patterns and Structures*, Holt, Rinehart & Winston, Inc., New York (1966).

year course, and was quite popular when it first appeared. In this series, the student gets very limited experience in actually making measurements. There is little development of an understanding or appreciation of measurement and its use. The approach to measurement is to learn to read the correct unit from a ruler, scale or cup; to learn the formulas and tables for weights and measures, and to work conversion problems.

Book I has a lesson on liquid measurement in customary units. The students are taught the relationships—"2 cups measure the same as 1 pint," etc. The lesson on weight, in customary units, consists of exercises in reading a scale printed in the text; students do not weigh anything themselves. There are four lessons on linear measurement, all in customary units. Students are shown how to make an inch ruler, and how to read from a picture of a ruler, and how to use it(!) to measure objects and line segments pictured below it. There is no "hands-on" work.

Book II devotes about a week's time to measurement: The lessons are of the same type; that is, in the lesson on liquid measure, the emphasis is on learning the words for the units of capacity, and the rules for the relationships between them—"write the word *cup* on the board. . . write the sentence '1 pint measures the same as 2 cups.' " The lesson on weight now has the students read a pictured scale to the nearest ounce, and read a Fahrenheit thermometer in the lesson on temperature. Although the base-10 Hindu-Arabic system appears in Book I, it is not related to decimals until Book IV, when decimal fractions are introduced in a 2- or 3-week unit. A knowledge of fractional numbers is the basis for understanding decimals, and the text reminds us that "decimals help in keeping track of money."

Book III has a 2-week unit on measurement. The metric system is not introduced; however, we do get "measures of long ago," the cubit, pace, and the ell. The absence of manipulative experience continues.

A metric unit appears for the first time as a supplementary topic in the last chapter of Book IV. In the two lessons on linear measure, students learn that a meter is "3 inches longer than a yard"; meters and yards, centimeters and inches are compared and there are exercises in converting from one to the other.

In Book V, the metric system makes a full-fledged appearance in the main body of the text in a chapter on measurement. There is a lesson on the metric system of linear measures—the meter, decimeter and centimeter. The metric system is introduced to the teachers as "the system used extensively in science." Students don't see a metric ruler or make any metric measurements, but merely compute conversions. In Book V, 10 weeks are spent on fractions and 5 weeks on decimals.

In Book VI, students at last read that "most countries of the world use a different system of measurement, the metric system." The teacher's edition states that the United Kingdom is now shifting to the metric system over a 9-year period. There are five lessons on the metric system. The units for linear measure are given, together with the relationships between them and a comparison to ours. Again, no measurements are made with a metric ruler. There are lessons in adding and subtracting metric measures: 5m7dm+2m9dm=? and multiplying and dividing them and regrouping them to the greater unit

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of measure, as if they were used like inches and feet. The gram is introduced, and there are exercises adding kilograms and grams; answers are not in decimal form, but in "so many kg plus so many g." There are a few problems in finding area and volume in both customary and metric units; however, the operation involved is numerical (multiplication), not measurement. The general treatment of measurement is as an arithmetic skill, not as a measurement skill at all.

There are no metric units in Books VII or VIII.

Elementary School Mathematics and its sequelae[4] is a widely used elementary mathematics sequence. This series consists of students' texts, teachers' editions, students' workbooks, and teachers' workbooks for grades K-6. The series stresses concepts rather than the mere mastery of skills, and offers enrichment exercises for "more advanced children." Centimeters are introduced in the 1st grade, and the series attempts to deal throughout with metric, customary and arbitrary units on an equal basis. The emphasis is on learning to measure with whatever unit is given. On the other hand, most computation and story problems are posed in customary units of feet, miles and pounds. This logically follows from the series' goal of relating numerical, arithmetic work to the child's practical experiences in the real world. Liquid measure is customary throughout. Conversion exercises from metric to customary units for weight and linear measure are included only for enrichment.

Half the units in Book I have lessons on coins, money problems and priced objects. Children handle real or play coins in many classroom activities, and manipulate money earned and spent in real life situations; the concepts of place value, addition, and subtraction are emphasized. The last unit is "Money, Fractions and Measurement." This 2-week unit includes two lessons on linear measurement and one lesson on liquid measurement. It introduces the idea of linear measure by using both inches and centimeters as units of measure. The centimeter scale was chosen for two reasons:

(1) to give the children the feeling that there is a certain arbitrariness concerning the choice of scale in linear measure;
(2) to provide an early introduction to the centimeter as an important unit of measure.

Students may cut out the centimeter-inch ruler from the book to measure various pictured objects. The ruler is color-keyed, centimeters in red, inches in black, and determination of which scale to use is made according to the color of the printed ink in each exercise. Gradually, the terms "centimeter" and "inch" are introduced. The lesson on liquid measure introduces the customary cups, quarts, and pints. Book II also gives bilingual treatment to linear measure for two lessons, and customary units for liquid measure in one lesson.

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[4] *Elementary School Mathematics*, 2d Edition, Addison-Wesley Publishing Co., grades K-6 (c. 1968).

School Mathematics I and *School Mathematics II* for grades 7 and 8, Addison-Wesley Publishing Co. (c. 1968).

Book III has a 3-week unit on measurement. Introductory lessons use the line segment, the square and the cube as common measuring units for length, area, and volume. This is followed by a lesson on using the appropriate unit (inch, foot, yard or mile) and then a lesson on measuring with inch and centimeter rulers. If centimeter rulers are not available, the teacher's guide suggests the children make their own, and directions are given. A "Follow Up" activity for the "more capable children" is to explore the metric system. Two lessons on estimation use primarily customary units. In two lessons on area, the square centimeter is favored for counting and estimating, possibly because it is a handy size and more exercises can be fit on a page.[5] Cubic inches, cubic centimeters and cubic arbitrary units are all used in the lesson on volume. Customary units are used for liquid measure.

Book IV has a 2-week unit on measurement, which reinforces the concepts of Book III. There is a "buried treasure map," for which the scale is given as "each centimeter means one mile." Again, area and volume are treated in centimeters, inches, and arbitrary units; perimeter is given metric treatment. The conversion exercises at the end of the chapter deal with finding the greatest number of the larger (customary) unit.

A 1-month unit on decimals appears in Book VI, and money is briefly related to decimal notation there. The metric system of measurement appears again as "enrichment." A table of comparative lengths in metric and customary units is pictured, and the children may study the table and then find the missing conversions. Further on, we find a "possible activity"—to interest "the more capable children in extending the metric system to weight, since this system is used for most scientific work." A table of metric weights and customary equivalents is shown, and students may complete the missing conversions. Another "possible activity" for "some space-minded children" is to convert space orbital data from miles to kilometers, and a table with conversion problems is shown.

School Mathematics I, for the 7th grade, and *School Mathematics II*, for the 8th grade, again use customary units, many nondimensioned units, and a sprinkling of metric units (centimeters) in the geometry sections. The rest of the text uses either nondimensioned units or the customary units for word problems.

Our observations on these sequences of elementary mathematics textbooks are consonant with the conclusion of a major publisher who made a metric study early in 1968:

> . . . in mathematics we find very little evidence of . . . systematic development of an understanding and use of the metric system at any level. There are separate units on the metric system and some exercises on converting from one system to the other, but no evidence of continuous development of a facility to use and work with the metric system.[6]

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[5] A square inch is rather gross but a linear inch is "just right."

[6] D. C. Heath Division of Raytheon Corporation, memo of 3 June 1968 from H. R. Mutzfeld to F. S. Fox.

The relatively low priority of the study of the metric system in elementary schools is indicated in the following:

> Measurement units are taught and used at every elementary grade level at least up through grade 8. Measurement is one of the major strands of elementary school mathematics. At the present time, the metric system does appear briefly in all arithmetic series. The percent of time spent on it as compared to the total time spent on measurement would be very low, not over 20 percent. When the metric system, especially linear measures, is introduced, it is introduced as a new system used by much of the world. Good teachers do use visual aids, and many elementary children become familiar with measuring to the nearest centimeter, for example. Pupils also encounter the need for metric units in their science classes. It is the great need in junior high school science that has led to much of the expansion of work on the metric system in arithmetic books. Other reasons for teaching the metric system include its connection with the decimal system pupils are learning, the cultural value, and the fact that it has been a *popular enrichment topic for some time.*[7] (emphasis added)

It is not hard to understand the experience of the Intermediate Science Curriculum Study (ISCS) Group. They pretested students early in the 7th grade on their facility with metric units to see if they need remedial work in this area before entering seriously upon the work of that curriculum:

> Our experience using this method (a test) of introducing measuring lengths with metric units suggests that many elementary science and mathematics courses are not getting students to handle the metric system efficiently. More than half of the 7th graders who took the test on using a meter stick that occurred early in our 7th grade materials were not successful with it.[8]

One may optimistically conclude from this statement that nearly half the students were able to make a metric measurement—we choose to interpret otherwise and to say that many 7th graders cannot make the simplest measurement in a decimal system, and that this betrays the failure of elementary mathematics to teach them either decimal concepts or measurement or the use of metric units. The deficiencies in teaching measurement and related materials which we have uncovered here, and the need to rearrange the elementary mathematics curriculum so as to teach decimal fractions earlier, etc., imply that substantial curriculum changes must accompany metric conversion. These would be comparable to the mathematics curriculum changes of the early 1960's, the so-called "new math," and ought to flow from the agreement of authoritative mathematics educators.[9]

[7] Charles R. Hucka, Associate Executive Secretary, National Council of Teachers of Mathematics, in a paper presented at the Education Conference, p. 2.

[8] "Experience of the ISCS Curriculum Group with the metric system," a report presented at the Education Conference, Burkman and Redfield, p. 4.

[9] These changes are needed whether we have a planned metric conversion or not, and together with other curriculum changes they are being considered by a continuing study group of the Conference Board of Mathematical Sciences.

Recommendation: In case a national program of planned metric conversion is adopted, authoritative recommendations for curriculum change in elementary mathematics should be endorsed by national organizations of teachers and educational leaders, and used as the basis for the curriculum embodied in the new metric textbooks. The substitution of metric for English measure, or the suppression of the latter, will simply not suffice. We must not fall into the trap of making "mechanical" conversions of mathematics textbook sequences which do not come to grips with the question of curriculum revision, lest we lose the opportunity that we have at this time for substantial curriculum reform in measurement and related areas.

We have obtained an authoritative and detailed recommendation from Professor S. Sternberg of Harvard University, which appears in appendix III. This recommendation parallels, and reinforces and amplifies, the recommendation developed by a metric study committee of a major educational publisher.[10]

Secondary School and College Mathematics

> . . . the college mathematics teacher assumes that his students are fluent in the use of any system of units which he discusses. In fact, he will bring a system of units into his discussion only when he has been assured that his students have such a fluency. Often, perhaps most often, his students are more fluent in the use of this system of units than he is. He is a follower, rather than a leader in this respect.
>
> It should be recognized that what I have said about college mathematics teaching is not true of secondary school mathematics teaching. In high school, the mathematics teacher *cooperates significantly* (emphasis added) in teaching the use of various systems of units for measurement. There are many reasons why this should be part of the mathematics curriculum. Learning how to use various systems of units for measurements fits very well with the building of arithmetic skills, and the mathematics curriculum provides a natural place to introduce some of these units some years before the student begins significant study of science.[11]

This task of teaching measurement in high school mathematics is apparently not accepted by textbook writers: the algebra, trigonometry, analytic geometry and elementary calculus texts examined by this Study were found to have very little in the way of measurement units, except that they appear in various problems set in concrete terms—problems which students call "word problems." Since it is generally conceded that anything not in the textbook is not likely to be taught, it seems likely that very little measurement is taught in high school mathematics. The high school mathematics

[10] D. C. Heath Division of Raytheon Corporation, memo of 3 June 1968 from H. R. Mutzfeld to F. S. Fox.

[11] Statement by Alfred B. Willcox, Executive Director for the Mathematical Association of America, at the Education Conference.

teacher assumes that the focus of teaching measurement lies in the science subjects in which measurement is used.

The key words in the passage quoted above are "cooperates significantly." The location of the responsibility for teaching secondary school students to handle real quantities appears to be the subject of some dispute between mathematics and science teachers. In mathematics, students learn how to handle word problems, but they seem to be unable to transfer that skill to their chemistry and physics courses. Perhaps the difference in the teaching style between the two subjects blocks the transfer. Perhaps a paralysis sets in when a student comes face to face with quantities in a real-world context, and with measurements that he has made himself. Failure to transfer may be related to ineffective teaching of estimation of real-world quantities and how to relate them to measurements made by oneself.

Some measurement is taught in the high school courses called "general mathematics." These courses are offered to students in grades 10-12 of the "general curriculum"—students who are not preparing for higher education or, indeed, for occupations in which mathematics will be used.[12] Their content is approximately the same as that of mathematics for grades 7 and 8 of the academic curriculum, and the texts used are grade 7 and 8 texts or general mathematics texts with the same content. In the absence of measurement activities, students have as much difficulty in "general mathematics" as they had in elementary mathematics.

Conclusion: In secondary school and college mathematics, measurement is not taught. The chief need for revision would occur in general mathematics texts and courses: activity-based instruction should be the foundation for the introduction of metric measurement at this level.

Vocational Mathematics

The vocational mathematics texts we examined covered the spectrum from a mere repetition (concise and in one volume) of the abstract mathematics customarily taught in secondary schools to the very practical manipulations of numbers in the context of shop problems. In the latter text, nearly every problem is related to a dimensioned drawing of a realistic shop "thing," and the book is profusely illustrated with halftones of shop tools and shop operations.

An example of work-related mathematics is the high school *Math Workbook—Food Service/Lodging*[13] developed by the staff of Project FEAST, a multidisciplinary curriculum offering a career ladder of studies for the hospitality industry. The curriculum trains students for the industry and for institutional housing and feeding; it is articulated among high school, junior college, and 4-year college courses. The *Math Workbook* first covers the essentials of mathematics as remedial work, and then it presents calculation exercises in a variety of business situations related to every facet of the oc-

[12] See the next section, "Vocational mathematics."

[13] H. W. Crawford, M. C. McDowell, *Math Workbook—Food Service/Lodging*, Institutions Magazine, Chicago (1970).

cupation, ranging from wage scales and guest checks to income tax and business ownership.

These books use English units exclusively, of course, and have common fractions everywhere, particularly binary fractions (halves, quarters, eighths, etc.) in the books for shop mathematics.

Conclusion: Vocational mathematics texts would need to be revised completely to be useful over the period of metric conversion. Besides introducing metric units, decimal fractions would have to be introduced earlier, and the extensive study of fractions now needed to handle English units of measure and binary fractions could be largely dispensed with.

Recommendation: The revisions needed in vocational mathematics textbooks should take place in two steps—the first step placing equal emphasis on metric and English units, and the second putting the English units in the background, but of course not to the extent that metric units are now in the background. The first revision would have to be prompt, and the second might follow after 10 years or more; this is in keeping with the revision schedules we observed in these texts.

Elementary Science

We examined two popular conventional science textbook series for grades 1-6, and some conventional general science texts for grades 7 and 8. In addition to describing the metric content of these books, we will summarize here the information presented at the Education Conference and gathered elsewhere concerning several novel elementary and intermediate science curricula. We looked for the present usage of metric units and tried to estimate the extent to which revision would be needed to make these materials suitable for use in a metric world.

The *Concepts in Science* sequence[14] consists of about 1,700 pages of student text in six volumes, and about 800 pages of teacher's guides and foreword material. It may or may not be accompanied by the *Classroom Laboratory* sequence of teacher's manuals,[15] containing about 40 "investigations" for each year. The *Classroom Laboratory* is designed to be used with or without the *Concepts* sequence of texts.

The texts use only English units up to grade 5, when a very few references to metric units appear. The *Classroom Laboratory* is oriented toward the observation of the things children see around them, and simple manipulations. It is practically devoid of measurement up to grade 5. In grade 6 there appear a few investigations dealing with the conversion between English and metric units.

It appears that about 600 pages of text and teacher's guide would need to be revised for a metric edition of *Concepts*. Many changes would have to be made in the instructions for classroom manipulations, and they are trivial: "a few inches," "a few feet," paper "1 inch wide and 6 inches long," "1 cup of

[14] Brandwein, *et al.*, *Concepts in Science*, Harcourt, Brace and World, Inc., New York (1966).

[15] Hy Ruchlis, *Classroom Laboratory*, Harcourt, Brace and World, Inc., New York (1966).

sand." These changes are relatively simple but one must present the following *caution:* Approximation should be preserved in making simple mechanical metric conversion. For example, "a piece of paper about 6 inches long" should be replaced in a metric edition by "a piece of paper about 15 centimeters long" (and *not* "about 15.24 centimeters").

Each unit of instruction—and there are about eight each year—includes a list of some 20 to 25 supplementary aids, films, film strips, extra reading, etc., all of which would have to be reviewed by the authors or editors to see which items are in need of revision and how soon they might be revised.

A more serious problem is the distinction that should be made quite early between *mass* and *weight*. This pedagogic issue is independent of the system of units, of course; but it must be resolved sooner or later because the units of mass and weight are different in SI, whereas they have the same name in other systems of units. The problem is essentially a cultural one and its resolution will depend upon the widespread acceptance of the distinction by more of the population, including teachers. A good way to begin would be to describe the contents of packages and cans as "net mass 500 grams" rather than "net weight" as at present.[16]

We examined a second popular primary science sequence for grades 1-8[17] and found that it has no mention whatsoever of the metric system of measurement. This series is oriented toward an explanation of things observed, and toward simple demonstration experiments which are mainly qualitative and seldom quantitative to any degree. There was only the faintest allusion to another system of measurement in connection with the use of the thermometer, which is identified as "a Fahrenheit thermometer, which is the kind of thermometer commonly used in this country."

We also examined part of the third edition (1965) of this sequence. There is some increase in quantitative measurement in the new edition, but it is still a very minor part of the whole. Again, the units of measurement are entirely English. The 1965 edition is a very complete revision of the 1961 edition, with a total rearrangement of the subject matter and new illustrations on every page. The 1968 edition is a minimal revision to qualify for a new copyright. It has more color pictures and student activities, but no increase in quantitative measurement or metric usage. Compared to the 1965 revision, the changes implied in producing a metric version are totally negligible: the sequence has about 2,300 pages of student text in 8 grades and about half as many pages in teacher's guides, and changes to metric units would have to be made on no more than 500 pages. However, the remarks made above about supplementary reading for students and teachers, films and film strips, etc., apply here too.

We were assured by the science editor of Holt, Rinehart and Winston that their new science sequence,[18] which is entirely in English units, could be totally converted to metric units in successive reprintings over the next 3

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[16] "Metric Units in Primary Schools," The Royal Society (London) (1969), p. 13.

[17] Herman and Nina Schneider, *Heath Science Series*, D. C. Heath and Company, Boston, 2d edition (1961).

[18] Fishler, *et al.*, *Science: A Modern Approach*, Holt, Rinehart, and Winston, New York (1971).

years if it were deemed appropriate to do so. A revised edition is scheduled to appear after 4 years, and it could easily be made metric.

The curriculum developed by the Commission on Science Education of the American Association for the Advancement of Science (AAAS), *Science—A Process Approach,* is entirely metric and appears to enjoy a growing use.[19] Xerox Learning Systems, the publisher of the teachers' guides, believe that about 1.5 million students are exposed to this curriculum in the current school year in grades K-4; grades 5 and 6 were published during the 1970-71 school year and it is not clear how many students it may have reached. The impact of this curriculum may be somewhat limited because the format of instruction does not include a textbook. In California, a constitutional amendment would be required to permit its adoption on a statewide basis, for the state constitution not only requires the state to furnish textbooks free to each student, but it further requires that the textbook be "the principal medium of instruction in every subject." Local districts may buy and use other materials, and indeed the wealthier districts do so without hindrance from state authorities, but occasionally at the hazard of harassment by local pressure groups. In Texas, on the other hand, the use of nontext materials is now accepted; and the state program director for science believes that *Science—A Process Approach* may reach as many as a third of the students in the state.

The way in which *Science—A Process Approach* came to be entirely metric was described by Arthur H. Livermore at the Education Conference:[20]

> From the beginning, the scientists who were involved in developing *Science—A Process Approach,* insisted that the metric system should be introduced early and be used throughout the program so that children would use the system with facility, and so that they would think in metric units. The teacher members of the writing team were not so enthusiastic about using the metric system, undoubtedly because they were not familiar with it and did not feel comfortable using it. As a result, a compromise was reached at the first writing session in the summer 1963. British-American units were used for measurement in kindergarten and grades 1 and 2. The metric system was introduced in grade 3.
>
> During the school year 1963-64 the new program was tried out in 12 school systems throughout the United States. Data were collected from the teachers and were compiled for use by the writing team in making decisions about revising the materials in the summer of 1964. The information about the use of the metric system in the pro-

[19] The distinctive features of this program are the use of instructional materials contained in booklets written for the teacher and used only by the teachers, and accompanying kits of materials designed to be used by both the teachers and the children; the sampling of the various fields of science in the topics covered in the exercises; the statement of objectives to be achieved by each exercise in the context of the basic processes of science; and the inclusion in the curriculum of methods for evaluating the pupils.

This project has been supported by the National Science Foundation.

[20] "The Elementary School Science Program of the AAAS," Arthur H. Livermore, presented at the Education Conference.

gram was quite favorable—the children accepted it and had little difficulty with it.

Perhaps because the teachers became more familiar with the metric system through teaching it, some of the teachers in the try out schools began to question the need for including the British-American system in the new science program. A typical comment was, "We have to teach British-American units in other parts of the curriculum such as math and social studies. Why not use just the metric system in *Science—A Process Approach?*"

Needless to say the scientists in the writing group accepted the suggestion immediately. The second experimental edition of the program which was prepared during the summer of 1964 had all references to British-American units removed.

In the second experimental edition the children were introduced to linear measuring in kindergarten with arbitrary units. Sticks of varying lengths, which the children selected names for, were used as units to measure various things in the classroom—tables, windows and so on. Then the metric system was introduced in the first *Measuring* exercise in 1st grade. The children started this exercise by again using stick units similar to the ones used in kindergarten. They then discussed the need for using some sort of standard units if the measurement made by one child were to be compared with those made by another. And so the meter was introduced as the standard unit of length.

The program went through several more years of tryout and revision, but the commercial version retains the pattern set in 1964—arbitrary stick units in kindergarten and metric units from 1st grade on.

Since the program is completely metric, there is no need to be concerned about whether children could convert between English and metric units. However, it is the experience of the innovation leadership in this program that some teachers find it necessary to teach children to convert from one system to the other, perhaps in response to the children's insistence on comparing metric units with English units.

Our philosophy is that by continually using the metric system children will learn to "think metric." The exercise, Estimations and Comparisons Using the Metric System, is an overt attempt to establish the habit of thinking metric. Some teachers continually encourage children to think metric by making estimations of lengths, volumes and so on. But others do not, and *the children come to think of the metric system as the one to use when they are doing science and the British-American system as the one to use for all their other activities.* (emphasis added)[21]

This report is noteworthy not only for the comments about the ease with which the teacher members of the curriculum development team were able to adapt to the use of only metric units in the curriculum, but also for the (be-

[21] *Ibid.*

lated) recognition by the development team of the language barrier which grows up between science and other activities ("the real world") when metric units are used only for science (and only metric units are used in science) in a world of experience which uses only English units.

The scientists and science teachers who designed the Science Curriculum Improvement Study (SCIS) curriculum[22] began with quite a different view from that of the AAAS on the use of metric units in elementary school. They reasoned from the start that it is quite impractical to teach a totally metric science curriculum in a world of English measurement. They use about equal amounts of English and metric units in their SCIS materials and in their teacher training programs, but the leadership believes that relatively little metric measure gets into the classroom and that whatever does get into the classroom is mainly imposed by the equipment used, such as meter sticks and graduated cylinders calibrated in milliliters. SCIS is estimated to reach about 250,000 elementary students.

Elementary Science Study (ESS) is a highly individualized program for grades K-8 in which the children have access to the materials for open-ended rather than teacher- or textbook-directed investigations.[23] In the *Match and Measure* unit for grades K-3, arbitrary units are used together with various measuring devices for the measurement of length, area, volume, etc. Children use uncalibrated measuring devices to compare things, and arbitrarily calibrated measuring devices, such as a wooden slat painted with blackboard paint so that chalk marks can be made and removed easily. The children are asked to develop other measuring standards of their own, such as washers, paper cups, etc. About a third of the 56 ESS units depend upon measurement. They range from *Water Flow* and *Kitchen Physics* to *Mapping* (with simple simulations of surveying instruments). Lists of equipment include things calibrated or dimensioned in both English and metric units.

ESS is presently used by approximately 2 million students, according to the sales figures of the publisher, the Webster Division of McGraw-Hill Book Company.

The Conceptually Oriented Program in Elementary Science (COPES) is a science curriculum for grades K-6 based upon selected "great ideas" or conceptual schemes in science.[24] The COPES curriculum is action-centered. Almost all activities require exploration of a nonreading nature to be carried out by individuals or in small groups. Basic skills, including measuring, are also developed. COPES is entirely metric.

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[22] SCIS is an ungraded sequential physical and life science program for the elementary school, under development at the University of California at Berkeley. The program, in essence, turns the classroom into a laboratory. The teaching strategy is for the children to explore selected science materials. They are encouraged to investigate, to discuss what they observe, and to ask questions. The teacher acts as an observer of the students' progress and as a guide.

The project has been supported by the National Science Foundation.

[23] The emphasis of ESS is to encourage students to work individually and independently, to devise experiments, and to direct their questions to the materials rather than to the teacher. There is little written material addressed directly to the children. Each unit has a teacher's guide and materials for the children to manipulate.

ESS has derived its principal support from the National Science Foundation.

[24] This project is supported by the U.S. Office of Education.

Intermediate Science

We examined several sequences of conventional general science texts for the intermediate grades, including the California textbooks for grades 7 and 8.[25] The latter use a mixture of metric and English units rather erratically, giving the wavelength of light in centimeters on one page, for example, and the wavelength of x-rays in inches on the next. The mass of the earth is given in power-of-10 notation in kilograms, and in pounds and tons using the "string-of-zeros" notation and as "so many million billion tons." Temperature is given in degrees Fahrenheit in the 7th grade and Celsius in the 8th grade, but instructions for carrying out chemical operations are given in milliliters in both. It appears that this sequence would require a rather thorough revision to produce a metric version; but, in view of the revision which might be undertaken to secure its place in a competitive market, a change to metric units would probably not be a great burden.

The other intermediate science sequences can be characterized in the same way with regard to metric conversion.

The Intermediate Science Curriculum Study (ISCS) is a large-scale instructional research and development project which is developing, testing, and disseminating a comprehensive science program for grades 7-9 based on a system of individualized instruction.[26] The unique feature of ISCS is that students have the opportunity to progress through the materials at different rates, and the sequence and scope of topics can be varied according to the students' interests, abilities and experience. The instructional package consists of printed text materials, specially designed laboratory apparatus, a self-assessment system with which the student can measure his own progress, teacher orientation materials, and standardized tests.

The content of the 3-year ISCS curriculum includes biological, physical, and earth sciences. The instructional strategy has been to deal first with fundamental material and to study later the application of fundamentals to other subjects. This leads to an inversion of the customary order in which subjects are taught and may give rise to some difficulty in the adoption of these materials.

Metric units are used exclusively in the ISCS materials. As it becomes necessary for the student to make a given measurement, he is taught to use appropriate measuring instruments that are calibrated in metric units.[27]

Introductory Physical Science (IPS) and Physical Science II (PS II) are curriculum developments of the Physical Science Group of EDC,[28] which is the successor to the Physical Science Study Committee (PSSC). IPS is used mainly in grades 8 and 9, and reaches about 20 percent of the students enrolled in those grades, while PS II is a sequel and is just emerging from pilot

[25] Navarra, Zafforini, and Garone, *Today's Basic Science—the Molecule and the Biosphere;* and Navarra and Garone, *Today's Basic Science—the Atom and the Earth*, Harper and Row, New York (1965).

[26] ISCS has been supported by the National Science Foundation and by the U.S. Office of Education. In its present developmental stage it already reaches about 70,000 students.

[27] "Experience of the ISCS curriculum group with the metric system," Burkman and Redfield, a paper presented at the Education Conference.

[28] These projects have been supported primarily by the National Science Foundation.

stages. These courses emphasize the study of matter, the interrelationship of matter and electric charge, and the different forms of energy and its conservation. Student laboratory work is of primary importance. To emphasize this, the laboratory instructions are incorporated in the body of the text; the results are not described. The philosophy of the Physical Science Group regarding the use of the metric system applies equally to the physical science courses, the high school and college physics courses, and the 4-year undergraduate curriculum in science and mathematics being developed to train physics and chemistry teachers:

> From the very beginning of the development of the PSSC physics course in 1956, it was decided that after acquainting students with the arbitrary nature of units of length, mass, and time, metric units would be used almost universally throughout the course and English System units would be almost completely dispensed with. This policy has been closely adhered to in all our later courses . . . . [I]n the current editions of IPS and PS II one must search carefully to find the few remaining uses of English units.[29]

Conclusion: *Conventional* science texts for the elementary and intermediate grades have not used significant amounts of metric measurement, nor is there any appreciable increase. Nonetheless, a small trend toward increased usage of the metric system in elementary and intermediate grades is discernible. It appears mainly in the *new* science curriculum developments, such as those discussed above. Of the 20 million elementary students in grades K-6, it is estimated that at least 4 million study the new science curricula. Of the 10 million students in intermediate grades 7-9, a little more than a million study these curricula.[30]

Secondary and College Science Textbooks

High school chemistry is usually the first course in which students obtain any serious acquaintance with the metric system. It is entirely metric and has so reflected professional chemistry for many decades. The metric system most frequently used is the cgs system, with the centimeter as the unit of length and the gram as the unit of mass or weight.[31] The cgs system,

[29] Judson B. Cross, "Use of the metric system in new science curricula developed by the Physical Science Group of Education Development Center," a paper presented to the Education Conference.

[30] Based on data provided by the National Science Foundation.

[31] Many chemists do not see any difference between mass and weight, and regularly and intuitively refer to atomic weight and molecular weight. For example, CHEM Study, one of the new chemistry curricula developed with the support of the National Science Foundation, used the chemical weight terminology. After several editions with a contracted publisher, it is now going into a "limited public domain" with three publishers authorized to bring out different revised editions: one of them will use the chemical mass terminology. It is estimated that CHEM Study reaches about 500,000 students a year, that is, about 40 percent of the students taking chemistry in high school.

The Chemical Bond Approach (CBA) is another new high school curriculum, developed with the support of the National Science Foundation. It uses the molecular mass terminology.

The distinction between weight and mass is further confused by the free use of the term Atomic Mass Unit in some chemistry texts which use atomic and molecular weight terminology.

rather than SI, is the customary metric system of chemistry, and indeed the mole rather than the kilomole, is the preferred unit of substance.[32] Modern textbooks use milliliter (ml) for the laboratory-sized unit of volume rather than cubic centimeter (cc or cm^3). Otherwise, the chief use of a non-SI unit in chemistry is the calorie, which appears frequently in the form of *kilocalorie/mole* for the specific energies of reactions and in other similar contexts: changing this unit to the SI *joule/mole* or *kilojoule/mole* (or to the physicists' non-SI but very useful *electron-volt*) will depend upon professional practice in chemistry.

The Biological Sciences Curriculum Study (BSCS) is a curriculum development supported by the National Science Foundation which produced three versions of a modern high school course in biology for use in the 10th grade. Each version approaches biology from a distinctive point of view: one uses a molecular-biochemical-evolutionary approach; the second uses an ecological-evolutionary approach; while the third uses a cellular-biochemical-evolutionary approach. These three courses are now estimated to reach 40 percent of the students enrolled in high school biology. Metric units are used, but there is relatively sparing use of any dimensions: for example, most photomicrographs and electron microscope illustrations are given in the magnification notation, for example "X 2500," which prevents students from thinking about the real sizes of things. In writing about very large numbers or very small dimensions BSCS uses power-of-10 notation but retains the string-of-zeros notation as well.

We examined a laboratory manual-and-workbook in biology[33] for advanced high school students or first-year college students and found that scientific observations were made in metric units. For example, the microscope was to be calibrated with a metric stage micrometer, and, of course, chemical operations of any precision were in metric units; but laboratory instructions were in English units generally, such as "net a 2-inch goldfish."

High school physics is less tightly bound to the preparation of students for other subjects than is college physics, and accordingly it is freer to adopt the metric system. There are texts which do just that, and there are those which attempt to teach as much as possible in both systems of units.

We examined the still popular successor to the long popular Dull and Metcalfe[34] and found that very nearly every mechanical concept is taught in both metric (absolute) units and English (gravitational) units, and indeed that

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[32] The formal definition proposed by the International Union of Pure and Applied Chemistry is "Mole: The mole is an amount of substance of a system which contains as many elementary units as there are carbon atoms in 0.012 kg (exactly) of the pure nuclide 12C. The elementary unit must be specified and may be an atom, a molecule, an ion, an electron, a photon, etc. or a specified group of such entities."

The unit is not yet part of the International System although it is recognized by the I.S.O.

[33] Abramoff and Thomson, *Investigation of Cells and Organisms*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1968).

[34] Dull, Metcalfe, and Williams, *Modern Physics*, Holt, Rinehart and Winston (1964).

Newton's second law, $F = ma$, is treated differently in the two systems of units, and all on the same page.[35]

A more modern book[36] begins with the description of motion (position, speed and acceleration) in the familiar English system of units, but suppresses them completely upon starting the study of dynamics and the second law. When forces are introduced they are measured in newtons or dynes and the whole issue of kilogram-mass *versus* kilogram-force (and pounds *versus* slugs) is finessed. English units appear later from time to time, but only very occasionally, and sometimes quaintly.

A recent conventional text[37] begins mainly with English units and uses kilogram-weight and kilogram-force even after having introduced the newton as a unit of force. The text is peculiar in that there is virtually equal use of English and metric units in the text but almost every problem is set in metric units.

PSSC Physics[38] was the pioneer science curriculum development program of the National Science Foundation. It now reaches about 40 percent of the high school students studying physics. The course is strongly oriented toward laboratory experience, with all laboratory measurements made in metric units. However, since large units like kilometers are not encountered directly in the laboratory, more familiar units—miles, miles per hour, and miles per hour per second—were initially used in that size domain. In going through successive revisions over the last decade, the course has become more metric. We did not find a problem stated in English units in the third edition.

College chemistry and biology courses reflect the rather complete use of metric measurements in those professional fields. Geology still uses both systems of units with roughly equal frequency, and, indeed, in geology textbooks one finds on occasion the same quantity given in both units simultaneously or the alternate use of English and metric measurement in succeeding chapters or even in the same chapter. This indicates of course that geologists are equally at home with both systems and that they expect their students to be able to follow. It is perhaps worth remarking that geology or earth science (or, more recently, earth-and-space science) is a notorious "gut" in colleges and curricula which have a minimum science requirement for all degrees. Thus many college students are exposed to these materials and this level of the use of metric units.

Most of the students who take college physics courses have other subjects for their major interests for which some knowledge of physics is a

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[35] In an absolute system, such as SI, unit force (one newton) is defined as that effect which produces unit acceleration (one meter per second per second) when acting upon unit mass (one kilogram). In the customary gravitational system, unit force (one pound) is defined as the gravitational attraction (at 45 degrees latitude) on a standard body, and unit mass (one slug) is that body which responds with unit acceleration (one foot per second per second) to a unit of applied force.

[36] Miller, Dillon, and Smith, *Concepts in Physics*, Harcourt, Brace and World (1969).

[37] Kelly and Miner, *Physics for High School*, Ginn and Company, Boston (1967).

[38] The Physical Science Study Committee, *Physics*, D. C. Heath and Company (1960, 1965); Haber-Schaim, Cross, Dodge, and Walter, *PSSC Physics*, D. C. Heath and Company (1971).

prerequisite or a requirement, as shown in table I. In recognition of the fact that English units are used almost exclusively in the fields of engineering mechanics and heat and thermodynamics, many introductory physics texts use English units to a greater or lesser extent in these parts of the course. There is a trend toward increasing use of the metric system and less usage of the English system, but it is slow. A few texts are now beginning to appear in which the English system of units is distinctly subsidiary, but many recent revisions and new texts present both systems on an equal footing.

Table I. Bachelor's degrees conferred in 1967–68 in fields in which an introductory course in physics is usually a degree requirement

Architecture	2,955
Biological sciences	31,826
Engineering	37,368
Mathematics	23,202
Physical sciences:	
Chemistry	10,783
Geology	1,689
Physics	5,038
Others	1,870

[Premedical and predental students usually earn bachelor's degrees in biological sciences or in chemistry.] (Data from Digest, p. 82.)

PSSC College Physics,[39] which was derived from the PSSC high school physics course reflects the trend of that project toward the reduction in the use of English units as described above.

Conclusion: At secondary and post-secondary levels, the study of chemistry is linked to the chemistry profession and uses mainly cgs rather than SI metric units. The study of physics is linked to the engineering profession, which uses English units in mechanics and heat. Textbooks reflect these connections and will change in response to changes in professional practice. Other sciences are bilingual.

Going Metric in the Social Sciences

The impact of going metric upon the social sciences will be indirect, but it is worthwhile to take a brief look at the area.

The social sciences comprise the disciplines of history, geography, economics, anthropology, political science, sociology, and psychology. In grades K-8, these disciplines are not taught separately as disciplines but are used as tools for the understanding of the subject studied. For example, when students study Japan, they look at a general picture of the country, which includes its history, economy, government, and geography. In grades 9-12, the disciplines themselves are taught as separate courses. Economics

[39] Physical Science Study Committee, *College Physics*, D. C. Heath and Company, Boston (1968).

would be the most affected by metrication because it includes the most measurement.

References to measurement in social science courses are minimal in grades K-3 and increases in grades 4-6, but measurement *per se* is not taught in the social sciences. Therefore, students should become familiar with measurements early in their study of mathematics and science. References made to measurements in a typical social science text include maps and quantities of various materials produced and consumed, imported and exported. In the curricula developed by national curriculum projects, such as *Man: a Course of Study*,[40] students are asked to analyze raw data and to deal with more and more measured quantities. However, in contrast to the laboratory-oriented natural science courses, social science courses, to the extent that they deal with measurement, deal with large amounts of things, and the measurements of these quantities are seldom crucial to the understanding of the material.

All measurements in social science courses are English. Even when studying a metric country, students deal with the country in the context of English measurements; and many students actually feel that the entire world uses English measurement. Social science teachers assume that their students are familiar and facile with our measurement system (from their mathematics courses), but many times the students are not. The teachers complain that the students have not learned measurement, but they rarely take the time to teach it—it's someone else's job to do that.

Metric conversion would require that social science teachers, like all teachers, learn the metric system promptly through existing or specially created inservice training mechanisms. Other changes in the social sciences due to going metric would be minimal: text revision would be taken care of in the normal scheme of periodic new editions.

Books for Use in Occupational Education, Secondary and Post-Secondary

Textbooks and other instructional materials used in occupational education, like all other components of occupational education, reflect the practices of the occupations themselves. These materials would need to be revised quite completely, and in each occupation in accord with the schedule for metric conversion in that field. Like other instructional materials, commercially produced texts for occupational education are reprinted annually and frequently revised.

A particular problem may arise in occupational programs for which curriculum materials are primarily produced in the schools in which they are used. The teachers who are the authors and editors of such materials may need to be released from part of their teaching obligations in order to have the time to make metric revisions of these materials. The early obsolescence of stocks of such locally produced materials would be another cost of going

[40] A 1-year course of study for upper elementary grades organized about the question "What is human about human beings?" It was developed by the Social Studies Curriculum Program of EDC, under grants from the National Science Foundation. The publisher is Curriculum Development Associates, Inc., Washington, D.C.

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metric, because it is economical to print 5- to 10-year supplies of these materials and to hold them in stock against future needs, whereas most commercial publishing houses print only a year's supply at a time.

SCHOOL LIBRARIES, WORKS OF REFERENCE AND ENCYCLOPEDIAS

Most schools have libraries of general reading, reference books, and encyclopedias, which supplement classroom texts and serve as a resource for both students and teachers. A program of going metric in the United States would call for a revision of textbooks, and libraries would likewise have to replace their reference books and encyclopedias with metric editions. This problem, like that of textbooks, would be handled in the normal revision and replacement cycle.

A school library is a dynamic collection and its holdings are replaced as needed to keep up-to-date. Since shelf space is limited and since a school library need not be comprehensive or historical, a book is discarded for every new book added. The life of a reference book is typically 10 years, and school libraries usually replace their encyclopedias every 5 years.[41] The library is also responsive to changes in the curriculum. For example, when the "new math" was introduced into the curriculum, appropriate reference books were added to the libraries' mathematics collections to keep pace with the change.

The funding patterns of school libraries cover a wide spectrum. Some school systems regularly set aside funds for curriculum change and for keeping the library up-to-date on reference works and encyclopedias. The library fund is usually under the control of the librarian, who may have the discretion to weight the expenditures according to her views of what the needs are. In such a case, rather heavy expenditures might be available at the appropriate time of a metric conversion.

We spoke to the editor of a very popular school encyclopedia.[42] The encyclopedia has about 10,000 pages, and approximately a third of them are revised each year. In view of this large and continuing revision program, one may expect that metric conversion would be no great burden upon the editorial staff. National guidance might be appropriate concerning the question of whether to have an intermediate stage of conversion, with English units kept in parentheses, before going to a final stage in which English units do not appear at all.

The publishers of encyclopedias encourage replacement on a 5-year cycle and offer trade-in allowances on old encyclopedias. Salesmen making sales to individuals ("parent sales") also encourage early replacement by offering a half-price trade-in allowance for editions less than 10 years old.

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[41] Outdated encyclopedias usually find their way into classrooms, where they serve as ready reference material.

[42] Donald E. Lawson, Editor-in-Chief, F. E. Compton Company, Division of Encyclopedia Britannica, Chicago, Illinois.

Conclusion: Replacement of library books and encyclopedias would not be an obstacle, in light of usual replacement cycles and given the preparation time proposed (below) to precede metric conversion in the schools.

Works of reference are frequently revised, and annual editions are not uncommon.[43] A realistic assessment of the problem was given by Dwight E. Gray.[44] In considering the possibility of introducing SI units into the third edition of the American Institute of Physics (AIP) Handbook, which is about to appear, he reported:

> . . . The consensus of the Handbook editorial board was that insistence on 100 percent usage of SI units in the new edition, at worst, might wreck the project completely, and, at best, would greatly delay publication. As a compromise, therefore, 3d edition contributors have been urged to use SI units wherever feasible, but have not been required to do so . . . . By contrast, the Optical Society of America has in preparation an optics handbook. Since this will be a brand new volume it is more nearly feasible to standardize on SI units, and I believe they hope to make such a requirement.

Handbooks constitute a valuable source of ready information, and they are widely used and relied upon in certain occupations. It has been common experience in the United Kingdom that handbooks cannot be revised quickly enough, and authoritative guidance may be required for metric usage in each field. Handbook revisions are seldom complete, and metric conversion would be a burden and an expense in many cases.

NONPRINT MATERIALS

Nonprint materials constitute a relatively small part of the resources of most schools, and relatively few of them need to be revised or replaced. They include:

- films, film loops, and film strips
- tapes and records
- picture files and picture packs
- art objects and art reproductions
- maps and globes
- "realia," that is, models, games, puzzles and other manipulative materials.

These materials turn over with a typical lifetime of less than a decade, for the valuable ones are handled by the students and wear out.

An instructional materials center (the successor to the school library) will also have typewriters, tape recorders, tape and record players, projection ap-

[43] *The Handbook of Chemistry and Physics*, Chemical Rubber Company, Cleveland, Ohio.

[44] "The Metric System and College Physics Education," a paper submitted by the American Institute of Physics and the American Association of Physics Teachers at the Education Conference.

paratus for the film materials, etc. Some of this equipment is similar to that found in home entertainment but is usually sturdier. These media are standardized, and they are more likely to be affected by the introduction of new media, such as super-8 in the place of standard 8mm film, than by metric conversion.

Nonprint materials are tied to the real world from which they are drawn, and to the extent that they have measurement in them they will reflect the measurement system of that world.

TESTING

The role of testing as an instructional device is the subject of some controversy. The substantial gains shown in the first results of the performance-contracting mode of delivering educational services were clouded with indications that the students were taught the text answers.[45] Yet many competitive high schools engage in overt "SAT preparation" courses offered in the weeks before those national tests are given; and, indeed, the very existence of the PSAT (Preliminary Scholastic Aptitude Test), billed as a warm-up exercise, shows that the concept is not only widely accepted but even encouraged by the test makers. Of course there is a difference between the "offense" charged to the performance contractors and the overt SAT cram sessions, but the difference is only one of degree.

There are purists in the testing field who insist that the role of testing is evaluation and assessment only and who feel that loading the test to encourage, if not force the adoption of, new materials is an exploitation of psychometrics. There are others who see testing as a motivating force—or at least an accelerator—for desirable change, while admitting that coercion of this sort is anathema to people charged with curriculum supervision and development.

There are thus two sides to the coin of testing. One side says, "You will know that a topic has reached general acceptance in the curriculum when it appears in the tests." The other side admits the feasibility and even the advisability of accelerating the acceptance of a given topic into the curriculum by pushing it in the tests. An example of the latter: it is generally conceded that the implementation of the "new math" in the secondary school curriculum was encouraged more or less gently by the fact that the Educational Testing Service was the employer of some of the main champions of the new math recommendations of the Commission on Mathematics of the College Entrance Examination Board and of the School Mathematics Study Group.

Both sides of the coin examined above are set forth with some slight reservations in the position paper of the American Society of Engineering Education:

> The real test of commitment to SI will come when educators, and those evaluating the results of education, begin to give examinations which include understanding and ability to utilize SI . . .

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[45] *New York Times*, 11 January 1971, p. 68. "Businesses as Teachers are Paid for Results."

A further step would be to encourage the College Entrance Examination Board (CEEB) and the American College Testing (ACT) to include SI in these aptitude examinations. This step would represent the beginning of a firm requirement of SI in education. Introducing SI into the Graduate Record Examination (GRE) used for graduate school admission would be another step.

The Boards of Registration for Professional Engineers might introduce SI gradually on an optional basis into license examinations. But as agencies of the individual states, these Boards could not legally require SI until the actual degree of commitment of Engineering practice gave clear indication that the need to be bilingual was closely related to the maintenance of public health, safety and welfare.[46]

We inquired briefly about the possible impact of going metric on the capital investment of the testing agencies in field-tested and proven questions. We learned from Educational Testing Service (Princeton, New Jersey) that the number of questions which might be affected was insignificant, and that there would be little effort involved in re-pretesting the questions to validate them. However, the Iowa Test of Basic Skills is newly revised this year in a form expected to be valid for 6 to 8 years. The test makers are in a position to supplement the standard form with a sequence of arithmetic test booklets for the transition period, so that each school system would be able to choose a test suitable for its own degree of metrication.

Conclusion: Testing as a component of the education industry is adaptable to changes of the sort one may expect will be involved in going metric, and some test makers are not opposed to participating in accelerating innovation by including new subject matter in their tests.

B. Teacher Training — Preservice and Inservice

PRESERVICE TRAINING AND TEACHER QUALIFICATION

"There are nine and sixty ways
of constructing tribal lays,
and every single one of them is right."
— Rudyard Kipling, *In the Neolithic Age*

We examined the certification requirements of the several states,[47] and found that many states do not require explicitly that their newly certified or

[46] "Going SI in Engineering Education," Cornelius Wandmacher, prepared for the Education Conference.

[47] E. H. Woellner and M. A. Wood, *Requirements for Certification*, 35th edition, University of Chicago Press (1970).

newly licensed elementary teachers have studied methods of science or mathematics teaching. In many states the entire mathematics requirement is a three-unit course in mathematics taken in college. The science requirement is frequently submerged in the general education block of the bachelor's degree, and the latter may be satisfied by a distribution of courses in which it is possible to elude the study of science altogether. One may *not* expect that science and mathematics teaching is done by specialist teachers in states with minimum requirements, for there is no such pattern in the use of specialist teachers. One may only hope that such deficiencies are recognized by supervisors and principals and compensated for by inservice training, since one of the goals of inservice training is the orientation and training of new teachers; but again there is no pattern.

The view of secondary school certification is more encouraging; most states require that the secondary school teachers of a given subject have an undergraduate major or a substantial minor in the field they are licensed to teach. A few states grant permanent licenses only upon the completion of a master's degree in subject matter, but most states grant a permanent secondary school certificate after the completion of a master's degree in education. Some, of course, grant permanent licenses to holders of B.A. degrees with no more than a minor in the subject after some experience teaching it.

These requirements are, to some extent, goals to be sought. The shortage of qualified teachers in the last two decades has made the waiver of the stated requirements commonplace, and emergency appointments have given rise to certification based upon teaching experience rather than upon a formal exposure to subject matter. In secondary school science, the teaching of physics is at a particular disadvantage in this regard, because very few high schools need a full-time physics teacher; and, as a consequence, a teacher of chemistry or mathematics is assigned to this task. A systematic attempt to remedy this situation is underway in the development at EDC of a college curriculum for future high school chemistry and physics teachers. This program is being pilot-tested with several colleges. Like programs are sponsored by the National Science Foundation in the Pre-Service Teacher Education program (UPSTEP).

We consulted a state-by-state outline of teacher qualifications for junior colleges,[48] which gives state requirements, state recommendations when there are no requirements, and some general practices in states which have neither requirements nor recommendations. For academic subjects, the qualification for a certificate or license or initial appointment is usually a master's degree in subject matter, leading to the description of a junior college education as "2 years before the masters." For appointments in occupational education, the requirements invariably include work experience in the subject to be taught, ranging downward from 5 years; rarely a master's degree, frequently a bachelor's degree, and, with about the same frequency, state certification as a vocational education teacher. This part of junior college and occupational education is in a state of change, and one of the more

[48] "To Work in a Junior College," American Association of Junior Colleges (1966).

Table II. Junior college teachers of science, engineering, and technology, by field and highest degree, 1966–67

(In Percent)

Fields	Total	Doctorate	Master's	Bachelor's	Other**
All fields surveyed*	100	9	74	11	6
Occupational fields:					
Agriculture	100	6	79	14	1
Engineering	100	2	64	28	6
Health	100	1	64	14	21
Technology	100	1	45	30	24

* Agriculture, anthropology, biological sciences, education engineering, health, home economics, library science, mathematics, physical sciences (classified as general, chemistry, earth sciences, physics, other), psychology, general science, social sciences, technology, interdisciplines, and other disciplines.
** 3% professional degrees, 3% no degrees, including associates.

frequent notations was "changes are under consideration," or words to that effect.

A survey made by the National Science Foundation[49] confirms this characterization of junior college teachers. Although 74 percent of all the teachers surveyed held the master's degree, the distribution is skewed for the occupational fields as shown in table II.[50] Occupational teachers have fewer doctor's degrees and less in the way of formal education than the average of the survey. Another characteristic is confirmed by the work experience of these teachers during the last 11 years: engineering, health and technology teachers have had much more "other" work experience in the recent past than the average—presumably their work was in the occupational field in which they were teaching. This data appears in table III.[51] Previous teaching assignments of junior college teachers were also studied, and the results show that many are "promoted" from high school teaching, particularly in science and mathematics. However, in the occupational fields more come from outside the teaching profession (table IV).[52]

Table III. Full time junior college teachers of science, engineering and technology by field and type of work experience, since 1955

(In Percent)

	Total	Teaching only	Teaching and research	Other experience, in addition to teaching and/or research
All fields surveyed	100	54	8	38
Occupational fields:				
Agriculture	100	58	8	34
Engineering	100	40	3	57
Health	100	42	8	50
Technology	100	38	5	57

[49] *Junior College Teachers of Science, Engineering, and Technology,* National Science Foundation, Washington, D.C., NSF Publication 69-3.

[50] *Ibid.* Extracted from table A-7, p. 34.

[51] *Ibid.* Extracted from table A-12, p. 37.

[52] *Ibid.* Extracted from table A-14, p. 39.

Table IV. Junior college teachers of science, engineering and technology by field and level of previous teaching assignment

(In Percent)

	Total	Junior college	4-year college	High school	Other	None
All fields surveyed	100	16	4	27	9	44
Occupational fields:						
Agriculture	100	13	1	27	5	54
Engineering	100	14	2	15	6	63
Health	100	16	4	23	13	44
Technology	100	12	3	14	9	62

The doctorate is effectively the teacher's license for college teaching. Anyone who has earned a doctor's degree should have no problem in going metric.

INSERVICE TRAINING FOR TEACHERS

There are many patterns and formats of inservice training for teachers at work. The following are a number of examples of inservice training patterns for elementary and secondary schools.

Some school systems expect their teachers to start their year in August, 2 weeks before the start of school in September, and devote part of the time to inservice training.

Some school systems have set aside 4 or 5 days each year as vacations for the children and meeting days for the teaching staff—Michigan used to have statewide or area meetings on such days, but they have given them up because of poor attendance.

Newton, Massachusetts, a large suburb of Boston, gives its teachers released time of a half-day each week for professional improvement.

A regional school district, Macomb (County) Intermediate School District (Michigan), organized to provide central services to the local school districts in the region, offers consultant services including inservice training programs of various kinds, offered mainly after school and on Saturdays.

Detroit offers a program of 5-hour workshops, either on Saturday or on two afternoons after school, typically a week apart. The teachers are paid a small stipend for attending.

In Texas, which has a statewide textbook adoption policy, workshops are held by the Texas Education Agency for the introduction of newly adopted materials. About a third of their elementary teachers have participated in a 1-week summer workshop on the AAAS science curriculum.

On the other hand, California, another "textbook" state, depends entirely upon the local school districts to provide inservice training in the use of new curriculum materials. The state department of educa-

tion chooses textbooks for all subjects in grades K-8 and provides them to the students; but the state does not have the financial resources to provide resource personnel or guidance for every new textbook adoption.

Atlanta, Georgia, has an elaborate television instruction facility which has been used in an imaginative way. A typical inservice course consists of a weekly after-school session with a lead teacher once a month for laboratory and discussion, and an all-day-Saturday session at the end of the year. The science supervisor told us that she trained 400 teachers a year in this way.

The United Federation of Teachers in New York City offers courses of various sorts, including "minicourses," which teachers may take to earn increments, to satisfy other requirements, and to update their knowledge.

There are school systems in which no formal program of inservice training exists, including some quite large ones.

Inservice training may be concentrated on the orientation of new teachers and on remedying deficiencies in their preparation, with little or no involvement of experienced teachers.

Evening, Saturday, and summer courses at colleges, universities, and extension centers must of course be mentioned here, but the choice of courses and studies is usually not under the control of the teacher's supervisor and the courses chosen are often not related to specific curriculum needs.

In general, resource people for inservice training include supervisors, college professors, leadership-trained teachers, and consultants from state, local, and other school administrative units. In a metric conversion program, resource people ought to include, in addition to the above, some high school chemistry and physics teachers who have been trained at brief workshops to be sensitive to the problems of elementary teaching.

Secondary school principals, teachers, supervisors and consultants are in accord that 8 to 15 hours of inservice training would suffice to prepare teachers for going metric.[53] This training would be a small part of normal inservice programs in schools and school districts which have substantial programs. Schools and systems with more modest inservice training programs would have to use whatever time might be available and perhaps stretch out the training over some months or even the entire year—this would be far from ideal. In school systems in which no formal program of inservice training exists, one may hope that the need for such training for metric conversion may prompt the formation of a regular program. Although this might appear to some to be a cost of going metric, the establishment of an inservice training program should be deemed a fringe benefit.

The Educational Research Service has surveyed 496 local school systems for the length of the school year for pupils and the number of contract days

[53] John F. Kourmadas, National Association of Secondary School Principals, in a paper presented at the Education Conference.

Table V. Number of days teachers are available before school opens in the fall, for professional meetings, and for system-wide inservice meetings *

Size of school district	Average number of days
100K or more students	5.1
50K to 100K students	4.7
25K to 50K students	4.6
12K to 25K students	4.0
6K to 12K students	3.8
3K to 6K students	3.7
Smaller systems	4.4

* Excluding days after school closes in the spring, paid holidays and other contract days. Some of the latter may be used for inservice training, parent-teacher conferences, or a day or two between terms.

for teachers.[54] From their survey results we have extracted the information which appears in table V.

In view of the housekeeping chores for school opening, the time available for inservice training seems marginally small. Furthermore, the results shown in table V for school systems with fewer than 12,000 pupils is probably biased upward, because schools which subscribe to ERS are probably richer and better administered and better able to conduct inservice programs and more aware of the necessity for them. A few districts responding to the ERS survey explicitly mentioned 6 to 10 additional half-days on which students are dismissed so that teachers may engage in inservice training.

It seems evident that much inservice training must occur in after-school and Saturday sessions otherwise unidentified, and that much of the inservice training needed for going metric would have to be organized to fit these opportunities.

Elementary school teachers will require the most intensive inservice training. In the transition period, the easiest conversion will be for pupils in the early elementary years. These children will, upon leaving school, enter into a world largely metric, and will learn on their own whatever customary measurement they need. Therefore, early elementary teachers must be especially at home with the metric system, for it is important not to confuse beginners with two systems of measurement. The problems of later elementary and intermediate school children, in grades 4-9, will be different. These older children will have had some experience with the customary system of weights and measures, both in school and outside; and they will have to learn the metric system as a second language. These different needs should be borne in mind in designing inservice training programs.

> Teachers in early grades reported that children learn the metric system quickly and easily. Several commented that they believed the reason

[54] *School Year for Pupils and Teachers 1969-70*, Educational Research Service, American Association of School Administrators and NEA Research Division, Washington, D.C., ERS circular no. 4 (1970). The ERS questionnaire was mailed to all systems enrolling 12,000 or more students, but only to smaller systems which subscribe to ERS.

> for this was that the children had had so little experience with British-American units and so had little interference from that system in learning metric units. In the upper elementary grades knowledge of the British-American system does seem to produce some interference. One evidence of this is the children's desire to convert from metric to British-American units after they have made a measurement.[55]

Inservice training for going metric should be tightly structured, well organized, and preferably condensed into a short span of time, ideally just before the teachers begin to teach new materials.

> The training should be similar to that which we hope they will use with their students, as teachers generally "teach as they are taught." We should consider some basic guidelines concerning measurement before going on. To begin with, measurement should not and really *cannot* be "taught" through a series of planned lessons. Learning to measure (especially in a relatively unfamiliar system) is a *gradual* process related to each child's *experiences*. Until a child has had the opportunity to experience in concrete, comparative terms what a gram and a kilogram, or a centimeter and a meter are, the term "five centimeters plus seven centimeters" is meaningless to him. Again, it is much like learning a new language. We have discovered that we cannot teach a new language (which the metric system really is) by teaching the vocabulary and grammar of this language. The most effective way to learn the new language is to *use* it in meaningful, everyday oral expressions. So too with the metric language, children will learn it best if it is not "taught" but experienced and used in some activity in the context of situations in which a child is actively involved (sewing, cooking, caring for animals, racing "hot wheels," comparing heights of roommates, etc.)[56]

The systemwide view of inservice training outlined in appendix VI-a must be fleshed out with detailed courses of training. A few programs would be adequate for the inservice training of all elementary teachers, because elementary school curricula are quite uniform across the country, and because most elementary classrooms operate as self-contained units with one teacher teaching everything. In school systems with mathematics and science specialists, other elementary teachers should have some metric background provided for them at the time that metric units are introduced in mathematics and science.

One such program, using educational television in part, has been outlined for us and appears in appendix VI-b. It is based upon a supervisor's success-

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[55] Arthur H. Livermore, paper presented at the Education Conference, p. 11.

[56] See *Match and Measure*, a working paper published by the Elementary Science Study of Education Development Center, Inc., Newton, Massachusetts, p. 3. (*Match and Measure* appears in its entirety in app. VI-d.) This passage is taken from a system-wide view of inservice training for going metric which has been developed for this Study by G. J. Putz. The recommendation appears in full in app. VI-a.

ful experience with inservice training for the use of *Science—A Process Approach.* A typical session would include a 20 to 30 minute television broadcast of a demonstration lesson made in the school system the year before, followed by about an hour of measurement activities for the teachers to carry out themselves. These sessions might be viewed by small groups of teachers, but an instructor need not be present. About six such lessons in a 2-week period at the beginning of the school year, together with one or two face-to-face sessions of about 20 teachers and an instructor, would suffice to impart the knowledge base of the metric system, some teaching tactics, and the use of metric equipment. This intensive program might be followed by a year-long program of monthly broadcasts of videotaped demonstration lessons on either of two subjects—on teaching measurement, or on teaching the new elementary mathematics introduced at the time that elementary schools in that community go metric.

A rather more extensive inservice training program has been outlined for us and appears in appendix VI-c. It is based upon the conviction that elementary mathematics, particularly elementary science, can and should be liberated from their traditional foundation in textbooks, and be built instead upon a free and flexible array of teaching units and materials. Over a 10-year period Elementary Science Study (ESS) has developed 56 units of this nature[57] that have gained a wide acceptance among many different kinds of schools, including traditionally organized schools that construct courses from ESS units, as well as nongraded and other unconventionally structured schools that encourage highly individualized programs of learning.

The experience of the ESS staff in running workshops for the introduction of these materials (and the concomitant changes in teaching style and approach) serves as the basis for the recommendation of an inservice training program to introduce the metric system and new ways of teaching measurement. *Match and Measure* is one of the ESS units which could serve as a foundation for this inservice training program. It is reproduced in appendix VI-d.

The recommendation might lead to a "tree" of workshops, beginning with a (series of) summer institute(s) to bring together regional teams for an intensive period of work and study: the institute participants would return to their homes and conduct similar regional workshops with the help of central staff if necessary, and the participants in these latter workshops would become the leaders for local workshop programs. Such workshops might involve explicit outlays of money for some staff salaries and particularly for travel for the participants. The supervisors and lead teachers who participate in the central workshops may well have year-round appointments in their own school systems, but some token stipends may be indicated for those who do not.[58] One-month stipends for all 10,000 summer institute participants would amount to about $3 million. Travel and the cost of operating institutes might

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[57] See page 54 for a brief description of ESS.

[58] The National Science Foundation offers $75 per week to science teachers participating in the summer institutes offered under its sponsorship. This level has remained unchanged for 13 years and there seems to be no lack of applicants to fill the positions annually made available in NSF summer institutes.

double the sum. This one-time expense may be compared to the NSF summer institute program which awarded grants totaling $19 million in 1969. These 10,000 supervisors and lead teachers would operate regional workshops to train teachers to run local workshops—all this in the framework of existing inservice training programs.

A workshop of this type might equally well be built around the AAAS elementary science curriculum *Science—A Process Approach.*[59] It could use the units developed for the processes of *Measuring, Using Numbers,* and *Using Space/Time Relationships.* The AAAS curriculum is more highly structured than that of ESS in terms of having specified objectives, tasks, appraisals and evaluations. The experience of the Texas Education Agency in introducing the AAAS curriculum might serve as a model.[60]

Recommendation: Since the knowledge base for the metric system of measurement is relatively meager, and since a THINK METRIC campaign should create the atmosphere, the emphasis in inservice training should lie in the strategies and tactics for teaching measurement in early and later elementary years, and in achieving at least the beginnings of an easy familiarity with metric units. It should be strongly activity-based because teachers generally "teach as they are taught."

A special problem of inservice training deserves to be mentioned: it concerns the small fraction of teachers (about 5%) who teach in school systems with fewer than 600 students (see app. II) and presumably, fewer than 30 teachers. Some special effort may well be needed to reach those who are geographically isolated and who do not take part in regular inservice training programs.

Secondary school teachers are highly specialized: teachers of science and mathematics probably do not need any special inservice training, because they are familiar with metric measurement already. Teachers of other subjects don't teach measurement at all, and so they will not need as much specialized training as those elementary teachers who teach in self-contained classrooms. They are in somewhat the same category as elementary teachers who teach together with science and mathematics specialists.

Inservice training for occupational education teachers is a much more diverse problem than inservice training for elementary school teachers. For the latter, a single strategy or a few similar strategies can be used to train about a million teachers. These teachers are normally "clumped together" in groups of six to 12 or more in a single building, and many school districts have hundreds of teachers under a single supervisory staff. By contrast, occupational education teachers are highly specialized and could not be reached effectively in such a manner.[61] In addition, each curriculum is intimately related to the occupation for which it trains and cannot go metric ex-

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[59] See page 21 for a description of this curriculum.

[60] C. S. Story, Texas Education Agency, Austin, Texas.

[61] In vocational education, there is the concept of the itinerant teacher-of-teachers who is an emissary of the state vocational education office. He may visit a district for several weeks and see the teachers in the district on a formal or informal basis, and then travel on to another district. This is more prevalent in agricultural vocational education than in industrial.

cept as that occupation does so. One solution to this problem is found in the fact that many occupational education teachers regularly return to work in their occupations for the summer or for periods of a few months to a year: this work constitutes a revalidation of their teaching credentials and, of course, keeps them up to date in the practices of their occupations.

Many of these teachers are local leaders in their occupations and serve on local apprenticeship, placement, or other advisory boards and, as such, would be involved in teaching metric usage to people already at work as well as to students in schools.

The above considerations apply to a static occupational education establishment. But occupational education is linked to industry and commerce, which are dynamic. We shall explore below the implications of these changes.

TEACHER "CONVERSION" IN ENGINEERING EDUCATION

Education is perhaps the least part of the problem of going metric in engineering. Given a time scale for metric conversion which would pose no major difficulties for industry, engineering education would be able to follow and produce qualified engineering graduates fluent in both measurement languages.

Perhaps the greatest difficulties will be experienced by the faculty members who teach engineering design, for they will be required to

> acquire and transmit a whole new basis of judgment. The wise admonition constantly given students to "look at the results of a calculation and see that it 'looks right' " will take on much new meaning for the teacher and student alike.[62]

Changes in engineering laboratory practice are discussed on page 56, and changes foreseen in the structure of the engineering professions are discussed in appendix VIII: both appear to be much greater challenges to engineering education than going metric.

C. Instructional Equipment

ELEMENTARY SCIENCE

> Science has come to play a more important part than ever before in the curriculum of the elementary school. The central emphasis of most of this new science has been that children should learn from nature, from setting and carrying through their own investigations. Thus it is laboratory work and field work, rather than the use of texts and

[62] "Going SI in engineering education," Cornelius Wandmacher, a paper presented for the American Society for Engineering Education at the Education Conference.

> lectures, that dominates this new development. Teachers' guides are often accompanied by kits of apparatus, specially constructed for particular uses the curriculum designers had in mind. Such equipment has proved its usefulness, and through its use many teachers have discovered that laboratory science in the classroom can be an exciting educational adventure.
>
> As schools tackle an ever wider range of science topics, however, the collection of special kits does not really add up to a generally well-stocked, reasonably priced elementary school laboratory. As teachers and children are liberated from set lines of study, moreover, and develop the capacity to pursue investigations where interest and opportunity lead, it becomes imperative that the school have a wide range of simple equipment and materials to meet planned lesson needs and for improvising new apparatus as unforeseen investigations are undertaken. The design of apparatus is not the least of the scientist's skills. The ingenuity and manual skill which may be called forth from children in producing apparatus to meet their own particular needs are likewise an important part of science in the classroom. The child who has built his own apparatus from familiar materials is more likely to relate his findings to the everyday happenings in the real world outside than are those whose experience is limited to the "conjuring trick" atmosphere of the ready-made science kit.

These words are taken from the introduction to an inventory of the things that some science educators think ought to be on hand in a classroom, or at least available in the school's stockroom.[63] The inventory ranges from blocks and tiles to microscopes (about a third of the entire cost), assorted tools, miscellaneous hardware, materials to be consumed during a school year, and junk. The list of measuring equipment seemed to be about equally divided between metric and English, with perhaps some slighting of the metric. Many of the items on the list, both materials and equipment, are "scroungeable," and any such cast-off equipment would use English measurement. The cost of the measuring apparatus is somewhat over $100; it is a small fraction of the total inventory cost of about $800. A school system which is prepared to provide expendable supplies of this character would have little difficulty in providing the modest additions needed for going metric.

SECONDARY AND POST-SECONDARY ACADEMIC EQUIPMENT

In this category we find biology, chemistry and physics laboratory and lecture-demonstration equipment, geology maps and field equipment, and the equipment of engineering laboratories.

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[63] "Science Equipment in the Elementary School," Elementary Science Advisory Center, David Hawkins, Director, University of Colorado, Boulder 80302 (March 1967).

Measuring apparatus in chemistry and biology is mainly metric already, reflecting the practice of the fields. The amount of measuring equipment that would have to be replaced in general physics laboratories is negligible, and, at any rate, it undergoes a general replacement or renewal in a period of time comparable to any proposed period of metric conversion.

Geological maps are usually given to scale—typically 1:24,000 for the quadrangle maps of the United States Geological Survey on which

1 inch = 24,000 inches = 2,000 feet or 1 cm = 24,000 cm = 240 m.

(These maps have mile scales on them so that the user may avoid the tedium of converting inches to miles.) Tapes and stadia rods for surveying are relatively inexpensive items and comprise a small fraction of the investment in equipment for geology field work.

The classical view of engineering laboratories is set forth in the following passage:

> Engineering schools typically have large investments in experimental laboratory equipment, almost entirely in English units. It will take many years to supplant or convert this commitment. Although much engineering laboratory equipment is becoming more scientific, it is also becoming more expensive to replace.[64]

A contrary view held by others is based upon the observation that technology has become a domain of rapid change, and that in order to keep academic engineering current and abreast of change, it must be adaptable to the changes as they occur. In this context, the investment in big and expensive permanent instructional equipment is a thing of the past. There is a movement in engineering education toward an exploratory laboratory which can be assembled at much less expense than the conventional laboratory. This notion calls for smaller items of equipment in the college laboratory and moves out of the college laboratory into the industrial shop or other engineering surroundings for students to gain experiences with large equipment and practical problems. Movement in this direction might be encouraged by the speedier obsolescence of laboratory gear calibrated in English units.[65]

EQUIPMENT IN OCCUPATIONAL EDUCATION

An estimate of the total investment and conversion cost in shop, laboratory, kitchen, and field equipment in occupational education can in principle be obtained by finding out how many "shops" there are of each kind and what a typical inventory and conversion would cost for each kind of shop. One should be able to arrive at a national total initial cost, and a conversion cost, by combining these data. We shall see that only the very roughest estimate can be made.

For a first try, we shall combine the numbers of teachers given in table VI, with the equipment lists of appendix VII, under the assumption that each

[64] "Going SI in Engineering Education," Cornelius Wandmacher, for the American Society for Engineering Education, presented at the Education Conference.

[65] Newman A. Hall, Commission on Education, National Academy of Engineering.

Table VI. Teachers and students in Federally aided vocational education classes, by type of program, 1968

Type of program	Teachers*	Students*	Students/ teacher	Subclass- ifications**
Agriculture	12,278	851,158	69	8
Distributive	8,603	574,785	67	20
Health	6,508	140,987	22	19
Home economics	29,224	2,283,338	79	19
Office	31,405	1,735,997	55	11
Technical	10,318	269,832	26	28
Trades and industry	47,741	1,628,542	34	97

* Digest, pages 34, 37.

** Number of subclassifications for each type of program, as given in "Vocational Education Enrollment by OE Instructional Program," Planning and Evaluation Branch, USOE, 20 May 1970. (A computer print-out of enrollment and completion statistics as reported by the states for FY 1969.)

teacher counted in the table has a laboratory or other instructional facility equipped with some "average" inventory. The total investment can be estimated at $2 billion—this number may be wrong by a factor two, but it is probably not wrong by a factor 10. It is by far the major fraction of the instructional equipment held by American education. We shall explore here the questions of whether this estimate can be refined, whether a reliable estimate can be made for the cost of metric conversion, what replacements and modifications would be needed in metric conversion, and what overall patterns of change can be foreseen for the next 15 or 20 years, which should encompass any period of planned metric conversion.

Let us first ask: How many occupational education curriculum programs of each kind are there?

Until 1969, data such as those in table VI have been reported to the U.S. Office of Education (USOE) by the states, in summary form, by type of program only. The validity of these data and their usefulness to the leaders of occupational education, who are responsible for planning and executing its programs, have been criticized by the National Advisory Council on Vocational Education and by others, including the Appalachian Regional Commission. The latter made a sweeping indictment:

> There may be less reliable data systems for evaluating the expenditures of over three-fourths of a billion dollars (each year) of Federal, State and Local funds, but if they exist, they are not obvious to an anxious observer.[66]

Recently, the USOE has been charged by law to secure more detailed data, and these are now beginning to become available. The enrollments within the seven types of programs are broken down for the academic year 1968-69, and the number of resulting subclassifications in that breakdown is shown in the last column of table VI. (We have noted significant omissions in the "1969 printout," but presumably more refined data may be expected to appear in the next few years.)

[66] "The Status of Secondary Vocational Education in Appalachia," Research Report No. 10, Appalachian Regional Commission, Washington, D.C. (October 1968), p. 1.

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Before we leave the data of table VI, let us first note that the ratio of students to teachers depends upon the type of program, and that it varies by a factor three. Then let us ask several questions of these data:

Is it fair to say that a typical curriculum involves *n* students (where *n* may vary depending upon the type of program), and that the number of laboratories, etc., is therefore given by dividing the number of students by *n*?

Occupational education leaders say that's not a very good guess.

May one say that each teacher has his own occupational education curriculum, and that the number of laboratories, etc., is equal to the number of teachers?

They say that's not a very good guess either.

Another sample of data may be found in the summary and tabulation of the programs of the public community colleges of California.[67] In 1967, there were 139 different occupational curricula taught in 81 colleges. Since then 12 new colleges have been opened. Some occupational curricula are taught in almost every community college in California—for example, real estate, general secretarial, vocational nursing, and police science—while agricultural inspection and laboratory animal technology are each taught in only one college.

The American Association of Junior Colleges (AAJC) has conducted a census of occupational education programs in 2-year post-secondary schools.[68] Questionnaires have been sent out and returned, and the data they contain are being reduced by Professor Louis Wall of Western Illinois University, Macomb. The diversity of the programs reported has delayed the completion of the analysis until accurate classifications can be made by persons familiar with the programs themselves. Some preliminary analyses will appear in the form of a report of the AAJC;[69] while the raw data, coded and available for further analysis, will remain with Professor Wall. Presumably further surveys of this nature will be undertaken if this census proves to be as useful as the AAJC expects it to be.

Proprietary schools constitute a significant part of the occupational education resources of the nation. They are organized as profit-seeking, if not actually profit-making, activities. They are entirely dependent upon tuition paid by their students, and their success lies in placing students who will satisfy their employers. Consequently, proprietary schools are characterized by strong student motivation and efficient teaching of job skills. Recent Federal legislation permits public school systems to send their students to proprietary schools with tuition paid in part by Federal vocational education funds. Some proprietary schools seek regional or professional accreditation

[67] "A Guide for California Public Community Colleges," Bureau of Vocational-Technical Education, The California Community Colleges, Sacramento, 4th edition (1968). Each college has transfer and other programs, in addition to the occupational curricula listed in this catalog.

[68] AAJC, 1 DuPont Circle, Washington, D.C., is a coordinating and information-exchanging body whose membership includes most of the nation's community colleges, junior colleges, and technical institutes.

[69] The tentative title is, "A National Census of Occupational Programs in Junior Colleges."

and the authority to grant associate and bachelor's degrees,[70] while others are concerned only with job skills and placement. In 1966, there were about 7,000 such schools with about 1.5 million students enrolled. A summary of private vocational schools is given in appendix IV. Proprietary schools are very flexible in adapting to change: when a need for workers arises in a given field, they can quickly staff and equip facilities and offer new curricula. They have relatively small investments per student in plant and equipment, and their teachers are untenured employees. Proprietary schools would have little trouble in following a metric conversion.

Equally elusive is the answer to the question: What are typical initial and conversion costs for a shop of a given kind? There is simply no such thing as a typical inventory, because of the wide variety of occupational curricula and the variability of the ways in which general principles (for example, those of the internal combustion engine) are overlayed, in teaching, with occupational needs and practices and local conditions. To continue the example, Diesel engine maintenance and repair may or may not be separated from internal combustion engine maintenance and repair, and may be taught in curricula entitled—

Automotive mechanics,
Truck (or Diesel truck) maintenance,
Heavy equipment maintenance (cranes, bulldozers, and earth moving equipment),
Stationary power plants,
Agricultural mechanics,
Marine technology, and others.

In any of these curricula, the local orientation may range from "keep 'em running," to complete overhaul and rebuilding, to running under optimum conditions tuned up by dynamometer and electronic measurements. The equipment needs for these courses vary from the simplest hand tools to the most sophisticated machinery and instruments. In addition, local conditions may dictate a dependence upon surplus or excess equipment[71] or upon industrial gifts of used or new machinery, or the school may have the freedom to purchase new equipment and to renew it frequently. With respect to metric conversion, these conditions, together with the philosophy of the faculty and administration, may give rise to such responses as—

We would modify our own machines—it would give the students some meaningful projects to work on. (Blue Hills Regional Vocational High School and Technical Institute, Canton, Massachusetts.)

It is not worthwhile to modify an old machine if modification should cost as much as 10 percent of the price of a new one—we would

[70] Proprietary technical schools are as concerned as conventional colleges of engineering about the changes foreseen in the structure of the engineering profession. They see it as a field of growth for their programs in technology. See app. VIII.

[71] Made available by the Federal government to educational institutions through programs administered by the state departments of education. "Surplus" equipment is often just a little bit better than junk—"excess" equipment is usually usable.

have to buy new machinery. (Milwaukee Area Technical College, Milwaukee, Wisconsin.)

Even the question of simple hand tool replacement may give rise to widely disparate answers in different shops in the same school. Here are responses to a question about replacing fractional wrenches with metric wrenches in the course of normal attrition:

I expect a complete turnover in hand tools every 3 or 4 years, and my budget provides for it. (Auto mechanics shop at Blue Hills.)

I haven't lost more than three or four wrenches in the last 3 years. (Auto body shop at Blue Hills.)

In the face of this endless variety imposed by the availability of funds, local needs, course structures and objectives, and teacher and student attitudes, we secured the equipment lists compiled for over a hundred different occupational curricula by the Division of Occupational Education of the North Carolina Department of Community Colleges. The lists themselves reflect local variations of the sort described above, but, nevertheless, we have studied them and tabulated our results in appendix VII. The modification costs were typically the replacement of gauges, thermometers, and linear scales as small components of larger systems; and the replacement of lead screws and nuts, dials, gears, and other components of relatively costly machines. Replacements and supplements include rulers and other measuring instruments, and small tools, such as fixed wrenches, drill bits, and taps and dies. In only a few shops would the cost of metric conversion approach 5 percent of the total initial equipment cost, and in none is it as high as 10 percent.

In this context, it is appropriate to point out that shop machinery is depreciated over periods of 7 to 15 years, although a good deal of older machinery is surely to be found in school shops. The need for modifications, etc., discovered in this Study correspond to a year's depreciation at most: in a planned program of metric conversion that cost would not have to be taken all at once, but could be spread over several years.

Conclusion: There are no adequate summary data on the numbers of types of occupational education "shops" or on their equipment holdings. Short of a door-to-door census and inventory, one can make only the roughest estimates of the total cost of conversion in this domain. However, the available fragmentary data indicate that the costs of going metric in occupational education would not be great: In a typical shop, it would amount, at most, to a year's depreciation, and in many curricula the cost would be negligible, i.e., less than a year's attrition and supplies budget.

PROJECTIONS FOR OCCUPATIONAL EDUCATION

We have discovered that only incomplete and marginally reliable information is available concerning our current programs in occupational education, so we must expect even less reliability in any projection of the future, par-

ticularly for a period of time long enough to cover a proposed metric conversion program.

Predictions for total enrollments in 2-year institutions of higher education have been set down by the Carnegie Commission[72] under three different projections for the next 30 years. These projections are accompanied by the realistic reservation that they should be reviewed every 5 years. No breakdown is given in these projections for the distribution among transfer, general, and occupational programs. Expected changes in the distribution, the trend toward the enrollment of more older persons (older than 25 years, say), and the availability of other forms of educational experience, such as a community service corps, an overseas volunteer corps, and the external degree program,[73] cast doubt upon the gross estimates of the Carnegie Commission's report.

A succinct statement was provided by a leader and planner in post-secondary occupational education.[74] In general, it appears that about 30 percent of the students enrolled are engaged in occupational, work-oriented, job-entry programs, taking into account national averages and recent trends in 2-year post-secondary institutions. Many institutions and many state systems expect this fraction to increase to 50 percent. The shift will not be at the expense of current programs of general education or transfer, but will come about as new funds and new building programs emphasize the occupational curricula of the programs of 2-year colleges in order to bring their offerings into greater accord with perceived national needs and students' desires. An implication for metric conversion projections is to be found here: It is generally expected that new occupational programs are more likely to be based in the behavioral sciences and health sciences, while existing programs, which are based more in the physical sciences and are consequently more measurement-oriented, will expand, but at a slower rate than the average.

A small conference of occupational educators was called with the (initial) intention of securing their views on the ways in which occupational education might be expected to develop in the next two decades, especially with regard to any interaction with metric conversion. The conference did not, in fact, spend much time on these forecasts. It seemed clear that the improvement of existing programs and the laying of shorter-range plans were of more concern, and that the problems of metric conversion in occupational education lie mainly elsewhere. However, information developed at that meeting has been used throughout the body of this Report.

A new approach to this issue may lie in the establishment in the U.S. Office of Education of a National Career Center for the Education Pro-

[72] *The Open-Door Colleges*, the Carnegie Commission on Higher Education, McGraw-Hill Book Company (1970), p. 33 ff. The three projections all assume, state by state, the continuation of recent trends in the fraction of high school graduates going on to post-secondary study. One projection assumes the continuation of the national average of 29 percent of undergraduates in 2-year colleges; the second assumes that 60 percent of future growth will be in 2-year colleges; and the third assumes that in each state the growth of 2-year colleges will follow the trend of recent years.

[73] "External Degree A Hope For Millions," New York Times, 11 January 1971, p. 50.

[74] John Grede, City Colleges of Chicago, (formerly of University of Michigan).

fessions.[75] In the face of the first numerical surplus of teachers in 40 years, this Center will examine the nature of some of our outstanding educational problems which we cannot expect to solve by sheer numbers of otherwise undirected teachers. Among its concerns, this new Center may throw some light upon needs for teachers in occupational education and, by implication, upon the nature of the occupational education programs which are likely to be needed and established in the immediate and near future. It might, in time, become the source of the type of detailed projections which we could have used in this Study.

There is a deep-seated contradiction—some would say schizophrenia—in occupational education between the mobility of the individual in our country and local responsibility for occupational education (and indeed for all education) in response to locally identified needs for trained workers. A recent study of the interaction between industry and occupational education deals almost exclusively with the mechanisms for securing local industrial encouragement and moral support for new programs to be financed by local, state, and federal funds.[76] While there are passages which refer to the need for local surveys to determine demands for trained people, there appears to be little quantitative consideration to national needs, except for the encouragement by national trade associations of programs to recruit young people into their trades (which one might have expected in the manpower shortages of the early 1960's). It seems likely that similar interactions may have to be developed between local governmental agencies and school authorities for the programs of service to social and health needs which are expected to develop in the next decade or two.

In a somewhat different vein, occupational educators are concerned about getting aspects of occupational education into the elementary schools. The white-collar blue-collar distinction so strongly projected in elementary education and in advertising and television programming creates a set of mind which directs secondary and post-secondary students into academic studies to the detriment of perceived national needs for graduates of occupational education curricula. (The last popular TV program with a worker for the hero, or anti-hero, was "Car 54," which expired in 1963. The plumber and electric lineman are always presented as friendly servants, while Daddy wears a suit to work and carries a briefcase.) In reaction, organized occupational education seeks, to some extent, to create new images of different kinds of careers as alternatives to white-collar careers based upon or following an academic education, and to project the images into education for the youngest children. An explicit suggestion was made at a recent meeting on vocational education—

> that "occupational preparation specialists" might be attached to the schools to see to it that the implications of education for occupation were attended to in all classes and at all levels and that all students were introduced to work skills, were given information about all

[75] Don Davies, "The teacher numbers game," *American Education* (October 1970).

[76] Samuel M. Burt, *Industry and Vocational-Technical Education*, McGraw-Hill Book Company, New York (1967).

kinds of jobs, and some understanding of the world of work and careers. Education of this sort—and especially a knowledge of the world of work—should begin in the early grades of elementary school and be continued through high school and beyond.[77]

Conclusion: There are essentially no data upon which reliable projections can be made for occupational education. This is true at every level of decision-making, whether it be local, state, regional or national. A commitment to set up any new curriculum is fraught with danger, for a sizable investment in equipment, space, and staff must be made before a program can be offered; and if students don't enroll in it, then administrative embarrassment can be acute.[78]

D. Adult Education and Workers on the Job

ADULT EDUCATION

To many Americans the words 'adult education' mean basket weaving or Japanese *ikebana*. To others the words mean high school completion or learning to read or write on a 5th grade level. All are accurate. Adult education in the United States is an umbrella term for voluntary, usually part-time programs, the fourth force in education, that level of nonacademic, often informal education beyond elementary, secondary, and university education.[79]

A detailed classification of "continuing" education programs has been given in an extensive study of the subject: [80]

I. Traditional Programs
   A. Adult Basic Education
   B. High School Level and Equivalency Education
   C. Adult Citizenship Education
   D. Occupational Training
   E. Avocational Education
II. Staff Training and Career Development for Government Personnel
   A. General Needs
   B. New Employees
   C. Skill Updating and Management Training for Middle-Level Career Employees

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[77] E. G. Mesthene, Program on Technology and Society, Harvard University (report on a meeting on vocational education, 31 October 1968, p. 2).

[78] William M. Staerkel, "When Enrollments Give Technical Education Deans Nightmares," *Technical Education*, (May/June 1970) p. 11.

[79] "Adult Education and the Metric System," Richard W. Cortright, for the Adult Education Service of the National Education Association, presented at the Education Conference.

[80] "Continuing Education," Melvin R. Levin and Joseph S. Slavet, D. C. Heath and Company, Lexington, Mass. (1970), p. 43. Part II of this classification is a reflection in continuing education of the trend in occupational education to train people for government service, a major thrust of the study.

D. The Federal In-Service Training Program: A Model for the State?

III. Citizen-Client Education
- A. Consumer Education
- B. Driver Safety Education
- C. Environmental Education

It is evident that many of the traditional programs in this classification fall under other sectors of this Study and need not be discussed separately. However, one must be aware that the needs of adult learners are different from those of children and that the adult learner will not respond to approaches used for children. Teaching methods and materials must be appropriate for adult education.[81]

In formulating adult instruction in the traditional programs, one must explicitly take into account the fact that different individuals will start at different places and that each is able to proceed at his own rate; and in particular, that they may have bits and pieces of knowledge for which adult education must fill in the gaps, and, on occasion, contradict what has been learned in the past. Manpower training programs have carefully considered these teaching problems.[82]

The THINK METRIC campaign might fall under part III, Citizen-Client Education, of the classification given above, although one would hope it might be more effective than driver-safety education has been, recognizing of course that there is an element of coercion and the learning task is easier in changing one's way of buying butter to "Net Mass — 100 grams" than in learning to fasten the seat belt provided in one's new automobile.

THE TRAINING OF WORKERS ON THE JOB

We have not made any extensive study of the problems of providing training for workers already on the job. Other components of the U.S. Metric Study have been assigned the primary responsibility for this sector: [83]

Component 2: the special cost analyses volunteered by over 150 manufacturing firms include personnel education among the cost factors estimated;

Component 12: the analysis of the effects on labor, conducted in cooperation with organized labor, was designed to focus on worker-owned tools and on employee education and retraining.

Nonetheless, we were able to secure the views of one large industry regarding the magnitude of the on-the-job training effort they would need, and

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[81] As an example, see *Hip Reader*, Cecelia Pollack and Patrick R. Love, Book-Lab, Inc., Brooklyn, N.Y. (1968).

[82] "Essentials for Planned Metrication in Manpower Training Programs for Adults," Donna M. Seay, a paper presented for the New and Related Services Division of the American Vocational Association, at the Education Conference.

[83] U.S. Metric Study Report, International Standards, National Bureau of Standards Publication, 345-1 (1970), pp. 43, 45.

we present them here to show that this component of education is substantial but readily manageable, and that it will be no major obstacle from the point of view of the employers.

At Ford Motor Company, the need for a variety of training programs has been established. They range from a 1-hour training period for clerical and administrative employees, much of which may be occupied by viewing a film; to a 48-hour training program allotting equal time to theory and to practice for scientists, engineers, and workers in the skilled trades. Ford estimates that about 80,000 workers would have to be trained, at a total cost of about $16 million, that is, at an average cost of about $200 per worker. About 95 percent of the cost is accounted for by the salaries and wages paid for the hours spent in (nonproductive) training.[84] General Motors has made similar estimates and confirms the general picture, with perhaps a small spread in the variety of programs and an explicit recognition of a period of inefficiency.[85]

It is worthwhile to put this cost item into perspective. The total cost of going metric at Ford is estimated at about 4 percent of a year's gross sales. In terms of 1969 sales of about $15 billion, this would be about $600 million. The cost of metric training, $16 million, would thus be only about 2.5 percent of the total metric conversion cost anticipated at Ford.

In making advance estimates of this character, it is virtually impossible to take into account the effects of a national THINK METRIC campaign. It seems reasonable to suppose that an early, imaginative, and widespread THINK METRIC campaign could make industrial training tasks easier and thus reduce the burden upon individual concerns. This would be an effective way to transfer some costs of metric conversion from the private to the public sector. However, the costs so transferred in heavy industry would be only a very small fraction of the total cost of metric conversion.

On the other hand, Ford and other large industrial concerns and their trade associations expect to produce their own training aids for going metric. One may expect these materials to be available at least to schools and perhaps to other segments of industry and to the public through industrial trade associations and other coordinating bodies.

Recommendation: A system of cataloging and critical evaluation of industrially produced instructional materials should be instituted as part of any national program of coordination for education. Materials and particularly films judged to be especially valuable ought to be widely disseminated, perhaps at the public expense, but at least with a public subsidy (it may be that the present reduced postage rate for educational films constitutes an adequate subsidy for this purpose).

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[84] William K. Burton, Ford Motor Company, Dearborn, Michigan.

[85] Roy P. Trowbridge, General Motors Technical Center, Warren, Michigan.

E. Some Concerns of Education That Are Not Truly Educational

In this Study we have tried to obey Bowen's dictum of concerning ourselves with our own business and not with other peoples'.[86] In this regard we recognize that many aspects of operating a school system are not properly the subject of our inquiry and we relegate them elsewhere, but we admit that they may involve some cost to the school system. And because people always ask about football, we cannot resist the temptation to make a few remarks about athletics at the end of this section.

School building practices and maintenance procedures are the province of the construction industry; size and substance of paper are the concern of the paper and printing industry; and the measurement of fuel and food belong to those respective industries. Although clerical and administrative employees of schools will have to learn to handle ordering and billing in metric units, their training is part of the general problem of on-the-job training of business employees; that too is outside the scope of this Study, except that the cost of their training will be a charge upon the education system. Some arguments about the cost of training nonteaching employees can be set down: The number of people involved is probably closer to half a million than to a quarter million,[87] and the cost of training each should be somewhat less than a hundred dollars.[88] But very little of that would be an out-of-pocket expense to school systems – most training could be carried out during working hours, for the time of school employees is seldom as completely accounted for as that of production workers. Using these assumptions and data, we may compute an upper limit to the one-time cost of training nonteaching employees, and compare it with the annual noninstructional budget of U.S. education:

$$\frac{640{,}000 \times \$100}{30\% \times \$70\ \text{B}} = \frac{\$64\ \text{M}}{\$21\ \text{B}} = 0.3\%$$

Many schools have nurses in attendance who regularly weigh, measure and examine students, and give first aid. Going metric in the nurse's office is properly the concern of the medical profession, of the scale and balance in-

[86] "Going Metric in the United Kingdom," Gordon Bowen, Director of the Metrication Board, a paper presented at the General Conference of the National Metric Study Conferences, Gaithersburg, Md., 16 November 1970, p. 3.

[87] An estimate of the number of people involved can be made as follows: about 70 percent of the total current expenditures for the operation of public primary and secondary schools in a recent year was attributed to the cost of instruction (Digest – p. 53). This mainly pays the salaries of teachers. The remaining 30 percent must include large expenditures for fuel and other supplies, and for contract work for maintenance, etc.; on this account one may expect that this fraction of the budget supports considerably fewer people in proportion, perhaps only half as many. If we apply the 70 percent to 30 percent distribution to *all* of education and to the 3 million teachers, then we may compute the number of nonteaching school employees.

$$\tfrac{1}{2} \times \tfrac{30}{70} \times 3{,}000{,}000 = 640{,}000 \text{ nonteaching school employees}$$

[88] Based upon Ford Motor Company's estimate of an average of \$200 per person for 80,000 clerical, administrative, technical and scientific people. Most school employees would fall into the first two classes, for whom Ford has proposed shorter training programs. The cost will depend drastically upon the strategy and the timing of the THINK METRIC campaign.

dustry, and of the thermometer industry. A beam balance costs $50 to $150—it is durable and could be modified at a cost of about 30 percent of the cost new. Thermometers are fragile and expendable—at any rate, they cost only a dollar each.

Other general equipment needs on a one-per-school basis or on a one-per-classroom basis include metric wall charts, kits of metric manipulative materials and other materials, the modification of paper-cutting boards with pasted-on scales, etc. These are all comparable in cost to the nurse's scale and thermometer.

We choose to make an exception here to Bowen's dictum, and to deal with the question of that part of athletics which is based in educational institutions. Some games are played over precisely dimensioned fields (tennis courts and baseball infields), and others over fields specified to lie within upper and lower limits (basketball courts), but most games are scored by counting or by the tally of score points. Sometimes ratios of numbers are important.

In track and field sports, achievement is measured in distance for jumps and throws and in time over a fixed course for races. Small amounts of new equipment would be needed in the form of tape measures and high-jump and pole-vault standards. The layout of metric track distances should present no difficulties, and American athletes regularly compete over metric distances in international competition every 4 years.

Let us take a moment to consider swimming and football, two sports that have precisely dimensioned facilities measured in *yards*.

Swimming is literally "cast in concrete." American swimming competition is standardized on the 25-yard (short-course) pool and on the 50-meter (long-course or Olympic[89]) pool. In general, the same people compete over both courses and the same champions excel over both courses. Economics will surely dictate that schools and colleges will build only indoor short-course pools for year-round use, and therefore competition will continue at this distance. There are only a few indoor long-course pools, notably in the Payne Whitney gymnasium at Yale and at the military academies.

Football is the only mass spectator sport in which measurement plays a central role. An argument can be set forth for keeping customary (yard) measure in football, based upon the observation that the game is played only in the U.S. and Canada.[90] On the other hand, a change to meters would be an important step in a THINK METRIC campaign, and it would open the field for new achievements and records. Putting aside the notion of playing on a 90-meter field[91] with stripes every 4 1/2 or 5 meters and a first down after 9 meters, one observes that the distance between goal lines has always been a hundred yards, but the location of the goal posts is not sacrosanct. In professional football the goal posts are now on the goal line, while in collegiate and

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[89] The term "Olympic pool" does not necessarily imply 50-meter length, and it frequently means just a large swimming pool.

[90] Discussion following the NCAA presentation at the Conference on Consumer-oriented Industry of the National Metric Study Conferences, Washington, D.C., 21-25 September 1970. (News report on the conference prepared by R. W. Carson, p. 10.)

[91] Ninety meters is 56 inches shorter than 100 yards.

school football the goal posts are at the end of the endzone, that is, 10 yards behind the goal line.

Finally, we must ask whether space is available for larger football fields. Many school and college fields are inscribed in quarter-mile ovals used for track events.[92] Jump pits and areas for other field events are often laid out within the oval and beyond one endzone of the football field. By relocating these facilities one can make room for a 100-meter field. However, much professional football is played in baseball stadiums, most of which have barely enough space for a 100-meter field, and some may not have enough space. In addition, there may be a few football stadiums especially built for the 100-yard field. If these are the governing considerations, then football too is "cast in concrete."

[92] One-quarter mile = 440 yards = 402.3 meters: 400 meters and multiples are common track distances for dashes, runs, and relays.

CHAPTER V — A PROGRAM FOR METRIC CONVERSION IN EDUCATION

The program proposed here deals with a schedule for metric conversion in education, recommends a lead time for the preparation of new educational materials, and suggests guidelines for making effective use of that lead time.

This proposal differs from the metrication program of the United Kingdom, which provided no such lead time. The reader may recall that in 1963 the British Standards Institute published the results of a wide consultation with industry which showed a large majority in favor of changing to the metric system without delay, and that in 1965 the President of the Federation of British Industries informed the government that its membership was in favor of changing and that it sought government support for the principle and timing. Accordingly, in May 1965 the government announced its support in the House of Commons and early in 1966 set up a committee to coordinate government and industrial policies. In May 1969, it appointed the Metrication Board. The guiding principle of metrication in the U.K. has been that it is voluntary and advantageous to all, and that any government agency would have advisory powers only. All this from a standing start in 1965 to completion in 1975.

At the Education Conference and in our data-gathering efforts we have frequently heard the opinion that very little could be expected to be done spontaneously in the U.S., and that there seems to be a very small likelihood that American industry will make requests or recommendations similar to those made by the Federation of British Industries. Indeed, we usually hear that there will be reluctance to take any voluntary steps in the absence of a national mandate, that is, a program sanctioned or perhaps even legislated by the Congress. Therefore, in designing the program outlined below, we have assumed that there would be a centrally directed (or coordinated) and

universally accepted national program of sufficient strength to bring about metric conversion according to a definite timetable, and we have further assumed a strong public relation campaign to THINK METRIC.

As a final prefatory remark, we would comment on the eagerness expressed at the Education Conference and by the people we have interviewed for the education sector to take a position of leadership in any national program of going metric. This implies that education be given a lead time of a few years and use it effectively, especially for the preparation of instructional materials and to implement a program to prepare the teachers of teachers.

We consider next the principal components of our educational system which would be affected by metric conversion: elementary school mathematics and science, secondary school science, undergraduate academic science, and occupational education; and we shall take them up in reverse order.

Occupational education, both secondary and post-secondary, is closely linked on a one-to-one basis with the practices of the occupations for which it trains its students; any schedule devised for the latter will perforce be appropriate for the former, and any other schedule devised for occupational education would probably be unrealistic.

The undergraduate academic science subjects are more or less metric already, except for engineering and the physics taught in the preparation of engineering students. Engineering education, like occupational education, will follow practice.

On a time scale suitable for elementary school mathematics discussed below, elementary and secondary school science would be accommodated with little effort, for metric revisions of the conventional instructional materials in these areas could be made on that time scale, while the new curricula are equally adaptable if not already metric.

Turning finally to elementary mathematics education, we find that it is quite independent of other sectors of the U.S. Metric Study. In our view, the chief concerns in this area are intimately connected with the need for some curriculum revision in elementary mathematics, and with the need to find better ways of teaching and learning measurement, estimation, computation with real numbers, and the practical use of the useful parts of mathematics (as distinct from the intellectual and abstract parts of it). An orderly metric conversion would require a lead time for the production of new curriculum materials and for getting them into the classrooms. Three years would be a comfortable length of time. If local planning were to follow national guidelines and adjust its schedules accordingly, then one might hope to achieve significant changes in the mathematics curriculum over a period of 2 or 3 years following the 2- or 3-year lead time.

The following recommendations assume the existence of a coordinating body for education, nationally representative of organized education, which can with authority set forth guidelines and recommendations for the effective use of the lead time.

The selection of this body is an exercise in educational politics. It should reflect the concerns of "the big six":

National Education Association,
American Council on Education,
American Vocational Association,
National School Boards Association,
American Association of School Administrators,
Council of Chief State School Officers;

as well as the concerns of the education agencies of the federal government: the U.S. Office of Education, the National Science Foundation; educational publishing: the Education Division of the Association of American Publishers; and others. For advice and implementation this coordinating body should be able to call upon curriculum innovation organizations and national educational organizations, such as the National Council of Teachers of Mathematics, the National Science Teachers Association, and the American Association for the Advancement of Science.

Regarding *textbooks* and other instructional and curriculum materials, this body should do the following:

(1) Advise school boards and other textbook purchasers, such as city and state agencies, to rearrange their schedules of new adoptions in order to be able to place metric books in the hands of students as soon as possible; and in particular, not to supplant currently held texts other than with metric ones (except of course for the replacement of losses and small expansions already planned).

(2) Urge authors, editors, and publishers to make suitably metric materials available as soon as possible, taking into account curriculum revision, as well as the mechanical conversion of customary units to metric ones.

(3) Issue guidelines to authors and editors concerning correct SI usage, and establish a clearinghouse for advice (a metric hot line, perhaps) to authors, editors, publishers, and others; to answer questions immediately; or to secure authoritative opinions on short notice.

(4) Endorse authoritative recommendations for curriculum change, particularly in elementary mathematics.

(5) Promote the publication in the periodicals teachers read of articles on the proper use of SI, on what changes in going metric and what does not change, on strategies and tactics for education in a world going metric, on criteria for judging instructional equipment, and on ways teachers may make their own equipment of free or inexpensive materials.

(6) Encourage papers and discussion on metrication at conventions and regional and local meetings of the National Council of Teachers of Mathematics, the National Science Teachers Association, and other teachers' organizations.

(7) Issue pamphlets and other short pieces of literature for teachers, concerning the educational implications of the introduction of the metric system, and encourage other organizations to do likewise in order to generate a diversity of styles and views. (A list of British

publications, both national and local in origin, is included in the Bibliography.)

In the field of *teacher training and retraining*, the central body should develop teachers-of-teachers programs, including the identification of problems to be faced in training elementary, secondary, and occupational teachers, the production of whatever materials may be needed, and the scheduling of workshops. Special attention should be paid to the problem of reaching isolated teachers. It would be appropriate to call attention to the deficiencies of preservice teacher training in mathematics and science education, and to seek ways to remedy them.

The central educational body should develop and proliferate *equipment modification schemes* for existing equipment, mainly in the instructional shops of occupational education. Plans should be provided for complete conversions to metric units, as well as for provisions for machinery to be useful for both English and metric measurements.[1] Manufacturers should be encouraged to make conversion kits available at minimum prices and to furnish machine drawings to schools that might want to make their own conversions as student projects. Local, regional, and state systems should be encouraged to coordinate the purchase and redistribution of equipment, so that new (metric) equipment may be placed in existing instructional shops and some of the older (English) gear may be taken into new shops for the transition.

The coordinating body should do the following:

(1) Establish a clearinghouse to identify and evaluate instructional materials, particularly films and videotapes made for on-the-job training, and to coordinate their use in schools.
(2) Establish a role for education in the THINK METRIC campaign.

Finally, the coordinating organization should make recommendations for ways to meet any special costs of metric conversion in education. At the moment, we see such costs only in the domains of inservice training and handbook revision, but some other small costs may appear which we have not identified here.

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[1] See *Machine Tools for Metric Production* and *Measure for Measure*, both listed in Bibliography.

CHAPTER VI — EDUCATION AND A THINK METRIC CAMPAIGN

> . . . the tasks of teachers in schools and those engaged in industrial training will be made easier when it is evident that the adoption of metric measurement is not a classroom discipline but a major change affecting every aspect of national life.[1]

Informing the public of specific measurement changes and the timing of those changes is essential to the success of metric conversion. People must feel that they are a part of the change: potential misunderstandings and apprehensions can be alleviated by a well publicized THINK METRIC campaign. Every sector of society will have a part to play in effecting the change, but the mental hazards and educational "costs" in each sector could be reduced by an effective and imaginative THINK METRIC campaign.

A complete campaign should include bus posters, billboards, radio, and TV spots,[2] and long and short TV and film productions including "Sesame Street"-like efforts and animated cartoons based upon the familiar figures of the Roadrunner, the Pink Panther, and Mr. Magoo. It should enlist teacher-figures like Julia Child, the Galloping Gourmet, and Bill Cosby; and an approach should be made to TV talk-show figures such as Joe Garagiola, Dick Cavett, and Johnny Carson. Going metric should be carried as news and for its intrinsic interest, and not as a public service gratuity.

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[1] *Going Metric: the First 5 Years, 1965-69,* the first report of the Metrication Board, 1970, London: Her Majesty's Stationery Office, p. 73.

[2] The Advertising Council is reported to have undertaken the design of a campaign based upon normal advertising strategy. They propose to survey the "market" and address the messages to the "consumers" via public service advertising so that the only direct cost would be that of production. ("Metrication, the Consumer and Advertising," Theodore F. Dunn, U.S. Metric Study Report, The Consumer, NBS SP 345-7.)

The creators of the popular comic strips, such as Li'l Abner and Peanuts, might be persuaded to participate. How is it that the British creator of Andy Capp has not been so engaged? Comic books seem to have become an accepted mode of education, and even the classics of literature now reach a wide audience in this form.

The THINK METRIC campaign ought to have more rimes for THINK than just one—perhaps some rimes for METRIC can be invented. The campaign should have some catchy tunes and jingles. Some imaginative thought should be given to WEIGHT and MASS.

A THINK METRIC campaign should aim for the early conversion of sportscasters. Perhaps the easiest thing to do is to paint the outfield barriers in baseball stadiums with their metric distances from home plate. Golf courses can be easily converted. Football was discussed above, and early and serious attention should be given to that question. After the 1972 (or 1976) Olympic Games, track and field events should be held over metric courses, with jumps and throws measured in meters.

Commemorative postage stamps might be issued to mark the beginning of a metric decade, and perhaps a new one could be issued each year to mark some special metric event, much as a Christmas stamp now appears each winter.

The toy industry has suggested that special toys and games might be developed to assist in consumer education.[3] In this connection, we have invented a "metric board" which is 1 centimeter thick, 1 decimeter wide, and 1 meter long. It is jointed and can be stacked up to form a cube 10 centimeters on the edge, that is, a liter; and the pieces are loaded to have a mass of exactly 1 kilogram (figs. 1 and 2).

Educators and scientists should be assured a role in the THINK METRIC campaign comparable to that of the media specialists in order to be sure that the message that is delivered with punch is the right message.

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[3] Toy Manufacturers Association, U.S. Metric Study Report, "Testimony of Nationally Representative Groups," NBS SP 345-12.

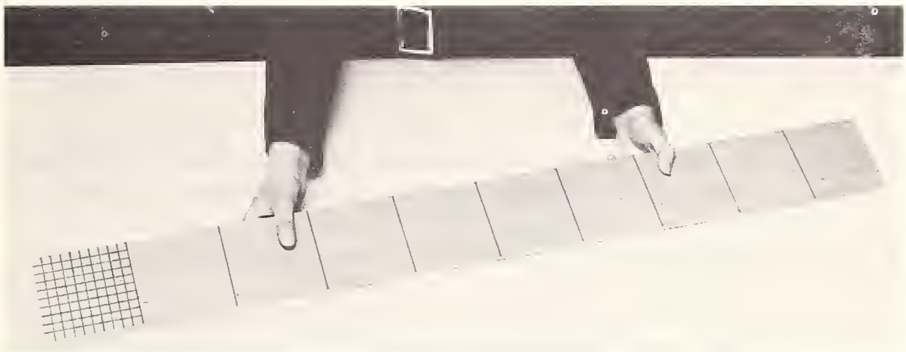

FIGURE 1. This is a meter-board. It is a centimeter thick, a decimeter wide, and a meter long. It is scored all around each decimeter, and one end is scored in centimeters. The scores are filled with blacking.

FIGURE 2. The meter-board can be disjointed and stacked up to make a liter-cube, or parts of one. The pieces are held together in the form of a board or cube by magnets or by dowel pins. *Note:* Each piece of the meter-board/liter cube has its mass adjusted to exactly 100 grams, so that the whole has a mass of one kilogram. It is packaged in a clear plastic container which is graduated at 100-milliliter intervals. It is a most instructive experiment to measure out a liter of water and discover that its mass is one kilogram.

Program of the Education Conference

Contributions to the National Metric Study Conference on Education, National Bureau of Standards, Gaithersburg, Maryland, 14 and 15 October 1970.

General Contributions

"Goals of the U.S. Metric Study"—Dr. Lewis M. Branscomb, Director, National Bureau of Standards

"Metrication and Education"—Professor Jerrold R. Zacharias, Massachusetts Institute of Technology

Curriculum Development

Intermediate Science Curriculum Study—Dr. Ernest Burkman

Education Development Center—Dr. Judson B. Cross

American Association for the Advancement of Science—Dr. Arthur Livermore

Project QPS—Dr. Sherwood Githens, Jr., Duke University

Higher Education

American Society for Engineering Education—Dean Cornelius Wandmacher

American Chemical Society—Dr. Stephen T. Quigley

American Institute of Physics—Dr. Dwight E. Gray

Mathematical Association of America—Dr. Alfred B. Willcox

American Institute of Biological Sciences—Dr. John W. Thornton

American Geological Institute—Dr. F. D. Holland, Jr.

Support Activities

American Library Association—Mr. Don S. Culbertson

NEA Division of Adult Education Service—Dr. Richard W. Cortright

Association of American Publishers—Mr. Paul Millane

Elementary and Secondary Education

National Education Association—Mr. Allan West and Dr. I. A. Booker

National Council of Teachers of Mathematics—Mr. Charles Hucka

National Science Teachers Association—Dr. Bobby J. Woodruff

American Industrial Arts Association—Dr. Edward Kabakjian

Association for Educational Communications and Technology—Mr. Richard G. Nibeck

Council for Exceptional Children—Mrs. Carol Fineblum

National Association of Secondary School Principals—Mr. John F. Kourmadas

Vocational and Technical Education

American Vocational Association:

Agricultural Education – William R. Jeffries
Business Education – Dr. Harry Huffman
Distributive Education – Dr. Neal Vivian
Guidance Education – Mr. Charles G. Foster
Health Occupations – Mr. Dale F. Petersen
Home Economics Education – Dr. Alleene Cross
Industrial Arts Education – Dr. Orville Nelson
New & Related Services – Mrs. Donna Seay
Technical Education – Mr. Frank Juszli
Trade & Vocational Education – Mr. Lee W. Ralston

Summary and Evaluation

Dr. Berol L. Robinson, Education Development Center, Newton, Massachusetts; and Education Research Center, Massachusetts Institute of Technology

Report of the National Education Association at the Education Conference

A position paper concerning the impact on school programs of a planned program of conversion to metric measurement, submitted by the National Education Association of the U.S., 1201 16th St., N.W., Washington, D.C.

This paper was presented at the Education Conference of the National Metric Study Conferences, held at the National Bureau of Standards, Gaithersburg, Maryland, 14 and 15 October 1970. It documents the history of the support of educational organizations for metric reform; and it provides a clear and cogent statement of the advantages to be secured, of the adjustments to be made, and of experience elsewhere. Teaching aids are suggested together with a schedule for going metric in education. Some estimates of the costs are attempted.

It is reprinted here as a resource paper of this component of the U.S. Metric Study.

PREFACE

This paper presents the official position of the National Education Association, established by action of its Representative Assembly, and such information as could be obtained within the limits of available time and resources with respect to the Association's interest in, and consideration of, the metric system over a period of many years.

We should note, however, that in a professional association of more than a million members, whose responsibilities range over the entire gamut of subject areas and cover all the learning age levels from nursery school through the university, wide variation in point of view and degree of interest is undoubtedly present with respect to the matter here under consideration.

In the preparation of this statement the NEA has had the helpful cooperation of many of its own staff units and also the collaboration of many of its departments, affiliated and associated organizations. In acknowledging their help, however, let it be emphasized that we do not presume to speak officially for these groups. This statement may not in all cases correctly or adequately reflect the interests or policies of the cooperating units. Indeed some of them will present supplementary or comprehensive position statements of their own which may, in some particulars, convey somewhat divergent points of view. Nevertheless, we believe that by and large this statement reflects rather faithfully the prevailing sentiment on the part of the teaching profession toward the adoption and use of the metric system in the United States.

Appreciation for valued help in formulating and evaluating this statement is expressed to the following organizations, for the most part NEA Units and autonomous affiliated and associated organizations: Association for Educational Communications and Technology; American Association for Health,

Physical Education, and Recreation; American Association of School Administrators; American Industrial Arts Association; Association of Classroom Teachers; Association for Supervision and Curriculum Development; Council of Chief State School Officers; Council for Exceptional Children; Home Economics Education Association; National Association for Public Continuing and Adult Education; National Association of Elementary School Principals; National Council for the Social Studies; National Council of State Education Associations; National Council of Teachers of Mathematics; National Higher Education Association; National Science Teachers Association; NEA Committee on International Relations; NEA Division of Educational Technology; NEA Division of Adult Education Service; NEA Journal Staff; NEA Office of Government Relations and Citizenship; and the NEA Research Division.

THE EDUCATIONAL IMPLICATIONS OF METRICATION

The interest of the National Education Association in the adoption of metric measurement is not of recent origin. A century ago a few distinguished members of the Association were advocating adoption of the metric system of weights and measures in the United States. And through the years many members have continued to support that position, especially some of the profession's foremost teachers of mathematics and science and some administrators and curriculum specialists concerned with program development.

The interest shown by teachers has by no means been universal and, except on the part of a few crusaders, has not been militantly agressive. Educators for the most part have believed that metric standards of measurement are superior to those in use and that *if adopted in the United States* it would be easier and less time consuming to teach the metric system. But few have regarded it as their duty to press for a change in public policy on this matter. Many have had teaching responsibilities which seldom involved the application or interpretation of measurement devices. Many educators as well as others, accustomed as they were to existing standards, were indifferent toward, or actually fearful of, any proposed change even if they would admit that *theoretically* there were many advantages.

For such reasons it is only in recent years that the voice of teachers on the subject of metrication has been heard, from greater numbers and in more insistent tones.

Association Interest a Century Ago

The National Education Association was only 12 years old when in 1869 it created a Committee on Coins, Weights, and Measures, with Charles L. Davis of West Point as chairman. In his report to the Association, at the

convention in Cleveland in 1870, Dr. Davis referred to his work on a similar committee of college educators which recently had presented a report and recommendations to another organization in Albany. His report, which he said was identical to that made in Albany, carried seven recommendations to NEA:

(1) That the Association continue to provide for intensive study of planned metrication—"all its bearings and all its consequences";
(2) That the Committee be authorized to include as a part of its printed report the statement made to the House of Representatives by John Quincy Adams in 1821 and a lecture by Sir John Herschell on "The Yard, the Pendulum, and the Meter";
(3) That all teachers be urged by the Association "to give special attention and study to this subject";
(4) That England, France, and the United States should be urged to make certain changes in the then existing values of the Pound, Franc, and Dollar and at the same time to fix a permanent ratio for them;
(5) That the Committee be authorized to carry on correspondence and otherwise promote its recommendations;
(6) That authors and publishers of textbooks for elementary arithmetic be urged to "exclude from future editions every currency not recognized and established by law"; and
(7) That the Committee be authorized to "ask the attention of the Government, and of all the associations for the advancement of science and knowledge, to the expedience of changing the value of the ounce Troy, and thus substituting a single weight for the three now in use."

Association records do not show what follow-up was made on this report either by the Committee or by association officers. Its significance lies in the fact that one hundred years ago, in 1870, change to metric standards of measurement was of sufficient interest and concern to educators that NEA created a special committee on the matter and heard its report at an annual convention.

Opinions of Distinguished Educators and Other Eminent Persons

From time to time professional educators acclaimed as leaders by their contemporaries have spoken out on behalf of conversion to metric standards. In 1880 the eminent superintendent of schools in Worcester, Massachusetts, Dr. Albert P. Marble, had this favorable comment but realistic forecast about the adoption of metric measurement:

> The metric system is very simple. Its introduction at once would be a great saving of time and money. But it will not at once be introduced. How was it with the decimal system of money? It was a century be-

> fore four-pence-ha-pennies and nine-pences disappeared from general circulation; and then they would not have disappeared but for the war. To apply the decimal system to these reforms [weights and measures]: The metric system will not become general in less than 100 years.[1]

The U.S. Commissioner of Education in 1944, John W. Studebaker, stated in the magazine *This Week:*

> The universal adoption of the metric system of weights and measures would pose no great difficulties for the schools. Indeed, if the schools were to teach only the relatively simple metric system the task of teachers and of students would be immeasurably lightened.[2]

Similarly in 1946 the long-time editor of the *NEA Journal* wrote:

> I am thoroughly in favor of the widest possible use of the metric system in education, industry, and everyday life. It is scientific, logical, and easy to use and furnishes a necessary base for international cooperation in science and industry. The use of the metric system throughout our life, based on a thorough teaching of the system in our schools, would be a great advantage. It would simplify the work of education. Children are confused and delayed in their learning by the miscellaneous and clumsy tables that have grown up in our English and American usage. If we will substitute the metric system, children must be brought to understand not only the system itself which is relatively simple but also the difficulties of making the change from present measures over to the metric scheme and the great advantage of making that change.[3]

Thomas Edison, Alexander Graham Bell, and George Westinghouse all were strong advocates of the metric system. So, too, was Andrew Carnegie, who said, "The present weights and measures of the United States of America are unworthy of an intelligent nation today."[4] Likewise, Arthur J. Balfour, noted in 1895 that, "Upon the merits of the case I think there can be no doubt. The judgment of the whole civilized world has long decided that the metric system is the only rational system."[5] In similar statements all through the years prominent educators and other leading citizens have in effect concurred in R. H. Pray's indictment in which he said, "The people in the United States have relegated themselves to one technological *last*!"[6]

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[1] National Education Association. *Addresses and Proceedings.* Washington, D.C.: the Association, 1880. vol., p. 39.

[2] Studebaker, John W., *This Week.* April 16, 1944.

[3] Quoted in the Twentieth Yearbook of the National Council of Teachers of Mathematics, *The Metric System of Weights and Measures.* N.Y. Bur. of Publications, Teachers College, Columbia University, 1948. p. 57.

[4] *Ibid.*; p. 118.

[5] *Ibid.*; p. 118.

[6] Pray, R. H., "The Metric System is Simple," Arithmetic Teacher **8:** 179, April 1961.

Significant Action by Various Educational Groups

Many associations of teachers whose work is directly concerned with the development of understandings and skills in the use of measurement standards have gone on record, at one time or another, in favor of planned metrication. Typical of such action are the following resolutions:

American Association for the Advancement of Science. (Adopted by the Council, December 29, 1922.)

Whereas, the metric system of weights and measures has not yet been brought into general use in the United States, and

Whereas, the American Association for the Advancement of Science has already adopted and published resolutions favoring the adoption of the metric system of weights and measures in the United States;

Therefore be it resolved, that the American Association for the Advancement of Science reaffirms its belief in the desirability of the adoption of the metric system of weights and measures for the United States, and recommends that units of that system be used by scientific men in all their publications, either exclusively or else with the customary non-metric units in parentheses.

Central Association of Science and Mathematics Teachers. (Adopted in Chicago, November 25, 1944.)

Whereas, the advantages of the metric system, well known to scientists and mathematicians, would be in harmony with the simplification procedures which will be a part of the post-war reconstruction program, and

Whereas, the metric system reduces all necessary computation in measurement to the operations of whole numbers, thereby greatly simplifying the learning of arithmetic by children, and

Whereas, there has been a long steady trend in metric adoption by 55 of the 57 countries of the world, and

Whereas, there is no probability among the nations now on a metric basis of going back to the English system, thus necessitating the use of two systems with the accompanying inconvenient and time-consuming inter-conversions instead of one simple system, and

Whereas, the close of this war will furnish an opportunity never before presented, when customs and habits have been torn loose from their ruts;

Therefore be it resolved, that the Central Association of Science and Mathematics Teachers go on record as favoring some form of legislation for immediate metric usage in those lines most feasible for metric adoption.

National Science Teachers Association. (Adopted at Pittsburgh, July 4, 1944, as the Association's first item of business.)

Whereas, the present practice in the United States involves the use of many and various methods of measurements which in total are a conglomeration which is cumbersome to learn and unwieldy to use, and

Whereas, the metric system furnishes the most simple self-related and convenient units which may be handled in decimals—just as is our monetary system, and

Whereas, practically every country in the world, except the United States and Great Britain, has long since converted to the metric system both internally and internationally, and

Whereas, in the United States many industries (e.g., electrical, American Medical Association, United States Army—about 90%) have already adopted the metric system, and

Whereas, the majority of men in service and many of those in industry are already familiar with the metric system, and

Whereas, at the time of retooling after the war it will be much less expensive for industry which is not already using the metric system to make such conversion, and

Whereas, in international relationships, especially trade, it will be of obvious value to use the same system used by other nations (except Great Britain) for periods ranging from over 20 years to over a century;

Therefore be it resolved, by the National Science Teachers Association, central organization of groups of people interested in science and in education in these United States, that this organization hereby urges Congressional action for post-war national adoption of the metric system of measurements.

Furthermore, the Association is hereby empowered to take any necessary action to promote the purpose of this resolution.

Significantly, the Board of Directors of the National Education Association at its next regular meeting voted to support the foregoing resolution of NSTA. While from such records as remain it would seem that this NEA "support" was chiefly "verbal," the endorsement given by the Board of Directors was an indication of a continuing, if somewhat latent, interest. It was also one recognized form of announcing official Association policy and as such constitutes a significant step.

Association of Teachers of Mathematics in New England, Connecticut, Valley Section. (Adopted at Northampton, Massachusetts, April 1946.)

Whereas, the present systems of measurement in the United States are cumbersome to learn and unwieldy to use, and

Whereas, the metric system reduces all necessary computations in measurement to the operation of whole numbers, thereby simplifying the learning of arithmetic and the use of arithmetic for computation, and

Whereas, the electrical, radio, jewelry, and optical industries, the American Medical Association, the national and international sports organizations, and the United States Army are now using the metric system in whole or in part, and

Whereas, the metric system has been adopted by 55 of the 57 countries of the world:

Be it resolved, that this Association go on record as favoring legislation by both the Federal Government and the various states for immediate adoption of the metric system throughout the United States, and

Be it further resolved, that this Association is hereby empowered to take necessary action to promote the purpose of this Resolution.

These resolutions are significant for several reasons: (a) they indicate that over the past half century a mounting interest in planned metrication has begun to surface in the educational groups most directly involved with the teaching and application of measurement systems; (b) they represent official group action, as contrasted with individual pronouncements; (c) they are unanimous in declaring that adoption of the metric system would be advantageous educationally—to both teachers and learners; (d) they concur in the belief that official action by the government (not merely education, persuasion, and piecemeal adoption) will be necessary for effective conversion to metric standards; and (e) they show that educators consistently are aware of, and concerned with, the noneducational impact of planned metrication as well as with its educational effects, i.e., with its social, industrial, economic, and diplomatic implications.

Recent Official Action

At the Dallas convention of the National Education Association in 1968 a resolution was adopted which for the first time committed the NEA officially to an *action program* in support of planned metrication—to association support of federal legislation that would bring about conversion to metric measurement. The resolution stated:

The National Education Association recognizes the importance of the metric system of weights and measures in contemporary world commerce and technology.

The Association believes that a carefully planned effort to convert to the metric system is essential to the future of American industrial and technological development and to the evolution of effective world communication. It supports federal legislation which would facilitate such a conversion.

The Association believes it is imperative that those who teach and those who produce instructional materials begin now to prepare for this

conversion by urging teachers to emphasize the rise of the metric system in regular classroom activities.[7]

The following year in Philadelphia a similar resolution was enacted. Then in 1970 in San Francisco the Association adopted its current resolution on the subject and made it part of the "continuing resolutions." These resolutions are reintroduced each year automatically, and thus continue so long as they are reapproved by the delegates in later Representative Assemblies. The text of the 1970 Resolution (C-16) reads as follows:

> The National Education Association believes that a carefully planned effort to convert to the metric system is essential to the future of American industrial and technological development and to the evolution of effective world communication. It supports federal legislation that would facilitate such a conversion.
>
> The Association declares that, commencing with the 1971-72 school year, teachers of all grades should teach the metric system as the primary system of weights and measures of the United States.

In the Association's Representative Assembly, where at any given time from 4,000 to 6,000 delegates participate in the business sessions, this resolution and the two similar ones of 1968 and 1969 sessions, respectively, were passed with virtually unanimous support. These repeated expressions of interest, and the specific action called for seem clearly to represent a new dimension in Association commitment.

In 1969 the National Science Teachers Association reaffirmed its traditional support for planned metrication in the following "position statement," prepared by its Committee on Issues and approved by the Association's Board of Directors, July 21, 1969:

> The National Science Teachers Association applauds the authorization by Congress in July 1968 of a study of the advantages and disadvantages of converting to the metric system. We recognize the need for an objective evaluation of all aspects of the conversion process and for sound guidance in planning and implementing those changes essential for a more extensive use of the metric system in the United States.
>
> The efficiency and effectiveness of the metric system have long been evident to scientists and educators. The desirability of a worldwide, uniform system of measurement is obvious; approximately 90 percent of the earth's population resides in nations committed to the metric system. For the United States, conversion appears necessary and inevitable. The Association therefore strongly urges that the metric system and its language be incorporated as an integral part of the education of children at all levels of their schooling.

And in the same year the Board of Directors of the National Council of

[7] National Education Association. *Addresses and Proceedings*, vol. 106. Washington, D.C.: the Association, 1968. p. 531.

Teachers of Mathematics restated that association's interest in a resolution which reads, in part, as follows:

> "*Be it resolved,* that the National Council of Teachers of Mathematics encourage the universal adoption of the metric system of measure.
>
> ". . . While the Board of Directors favors the universal adoption of the metric system, it is also aware of the complexity of this issue and is familiar with the history of many past attempts to effect such adoptions. The Board hopes to contribute in the long run to the adoption of the metric system through the contemplated NCTM supplementary publications on the metric system and through the encouragement of the President to speak out in its favor at appropriate opportunities."

Three state education associations report that they, too, have adopted resolutions which commit them to the support of planned metrication. Copies of these resolutions were not available for inclusion here, but the associations involved are: Illinois Education Association; Missouri State Teachers Association; and Pennsylvania State Education Association.

The Special Interests of Various Educational Groups

Among the NEA staff units and the organizations closely allied to NEA, which collectively are sometimes called the NEA family, many that have taken no official action and done little if anything to promote the idea of change to metric measurement are nonetheless aware of the issues. They are watching and listening with keen interest, knowing that conversion to metric measurement would have both direct and indirect impact on the programs and responsibilities of their members. Some have gone no further than to speculate; others are beginning opinion surveys and other evaluative procedures. Typical of such interest is that expressed by the:

Association for Educational Communications and Technology and by the related staff unit, *NEA Division of Educational Technology*—special interest in the equipment changes that would be made and in the need for new and revised audio-visual materials in the effective teaching of metric measurement.

American Association for Health, Physical Education, and Recreation—special interest in the use of metric units in the construction or modification of athletic areas and athletic equipment, and use of metric measurement in field events, swimming meets, and other athletic contests, including the impact of these changes on American interest, understanding of, and participation in international athletic competition.

American Association of School Administrators—concern about the implications for school management, such as purchasing by the new standards; maintenance during the transition period; construction plans; obsolescence and cost of essential new equipment. Also, the Association is aware of an inherent impact on curriculum development, supervision, and inservice programs.

American Industrial Arts Association—interest centers on how a new system of measurement will affect shop procedures, equipment obsolescence, and pupil achievement in industrial arts classes.

Association of Classroom Teachers—special interest pertains to the impact of planned metrication on both preservice and inservice preparation and on curriculum revision and the modification of classroom procedures. Also, the Association is interested in the extent to which metric measurement would, in fact, simplify the teachers' task.

Association for Supervision and Curriculum Development—special interest in what revisions of curriculum would be needed, including possible economies in time for teachers and students, and in the supervisory leadership which implicitly attends any major program change.

Council of Chief State School Officers—concerned with the total impact of planned metrication on a state school system: its administrative, financial, supervisory, and curriculum implications; its effect on teacher preparation and especially on pupil achievement.

Council for Exceptional Children—concerned with the potential simplification of teaching-learning procedures for slow learning children.

Committee on International Relations (NEA)—interested in the influence of a common system of measurement on the practical problems and effective communication of international travellers, especially teachers and students.

Home Economics Education Association—special interest in the "consumer education" which will be needed in home economics classes as students begin to use metric units in cooking recipes and for garment sizes, fabrics, patterns, and other household measurements.

National Association for Public Continuing and Adult Education and the related staff unit, *NEA Division of Adult Education Service*—special interest in the kind and amount of education that will be needed for effective use of metric measurement by adults familiar only with the current system.

National Association of Elementary School Principals and also the *National Association of Secondary School Principals*—concern with the impact of metric measurement on both the administrative and supervisory problems of a building principal, such as: changes in equipment and materials; teacher preparation; curriculum revision; and pupil achievement.

National Council for the Social Studies—interest in the extent to which our adoption of the metric system would contribute to the development of common worldwide understanding and effective communication. Also, the Association is considering the implications of the introduction of maps scaled to and interpreted in terms of metric units of measurement.

National Council of State Education Associations—special interest in the present attitudes of teachers toward the proposed change and in what would be the optimum timetable for conversion to new standards.

National Higher Education Association—concerned especially with: the potentially better preparation of students to use metric measurement in college classes, in science and mathematics; and with the colleges' new responsibilities in teacher preparation if a new system of measurement is adopted.

A brief poll of state education associations in late August 1970 brought out the fact that three have adopted resolutions favoring change to the metric

system: Illinois, Missouri, and Pennsylvania. In addition to the three state associations resolutions already referred to, there is some awakening interest in metrication among these state groups.[8] Exploratory studies, under state association sponsorship, have been made in both Kansas and Indiana. In the latter state a resolution will be introduced at the association's annual meeting in October 1970. In 41 states where no official action has been taken and no special study made, it is the opinion of the executive secretary in 28 of those states that a majority of the association's members would favor U.S. adoption of metric standards. In contrast, only four executive secretaries are of the opinion that a majority probably would oppose such a change. Nine of the respondents were too uncertain as to teacher attitudes to offer an opinion.

Each state secretary was invited to submit any *personal reaction* he cared to give, either pro or con. Six submitted strong supporting statements; none registered strong personal opposition. Significantly, too, only four of the 44 states responding indicated that they had little interest in the metric conference. Thirty-one were familiar with NEA's official position with respect to metrication; 12 admitted that they did not know what NEA's position was or whether there was an official position. One was misinformed, believing that NEA was officially opposed to any change. This poll reflects no widespread aggressive interest at the state association level, but like other indicators seems to denote growing awareness of, and interest in, U.S. adoption of metric standards.

Metric Measurement in Today's Schools

The one safe generalization about what, when, and how *anything* is taught in American schools is that *no two schools are doing it exactly alike!* However, the following observations with respect to metric measurement in today's schools seem to be generally valid.

First, instruction about the metric system in elementary schools—even the better ones —usually is brief and superficial. Occasionally it may be introduced as early as grade 6, but usually not until grades 7 or 8. The pupil may learn that there are metric units and learn the names of some of them such as meter and kilogram, through his general reading in English, social studies, or science classes. This, however, seldom leads to formal study of the metric system. If taught at all—and sometimes it is omitted—metric measurement is taught in arithmetic and/or science classes. The time and attention given to it varies widely but for the most part is quite limited.

Second, the teaching of metrics for the most part is *about* a system that "could be used" and that "some people use"; not as a system that "we are going to use, and you must learn to use." Even in science classes where metric measurement is used without conversion to imperial units the students learn it as the "language of science" rather than the measurement system for everyday use by all the people. For pupils in today's school metric measure-

[8] This poll was carried out with the helpful cooperation of the National Council of State Education Associations.

ment is merely a *second system,* a parallel system; not the *basic system.* They do not learn to "think metric." In their problems and even in the practice measurements they make with metric-scaled instruments—if any—they typically translate the metric units into the more familiar English units. They think about metric units in about the same way as about cubits, or fathoms, or furlongs. Teachers aware of the common shortcomings compare metric instruction as it is now given with the notoriously ineffective "translation method" in the teaching of foreign languages. What is needed, they say, is a direct approach: the *use* of metric standards until the pupil can apply them and "think metric."[9] It was the inherent difficulty in any such "translation approach" which led Donovan Johnson to say: "The successful teacher of mathematics is like a builder of bridges. He must build a foundation for any new concept for each student by using concrete experiences."[10] And another educator puts it this way: "Education in the use of the metric system will not succeed so long as pupils must be taught to *convert* metric to English and to *think* English. There must be *use* of one system to make the teaching of that one system effective.[11]

In spite of this obvious fact a great many elementary schools do not have a single meter stick, metric balance, or any measure of volume calibrated to show cubic centimeters or liters. Without such tools for application and direct experience, any instruction must necessarily deal with abstract ideas and the manipulation of numbers.

Third, research indicates that instruction in metric measurement is gradually improving, as schools move into contemporary mathematics programs. In the so-called New Math program more attention is given to number systems, especially the base-ten system. Newer texts and course outlines, too, seem to include more materials and provide more experience in actual metric measurement than could be found in comparable texts and courses of study a few years ago.[12] An aggressive experiment to improve instruction in metric measurement on a statewide basis is getting underway in Mississippi. The Director of this "Project for Metric Research" is Dr. John M. Flowers, Department of Science, University of Mississippi. Initial response to the program, which involves the mathematics and science programs of all grade levels, has been excellent and significant progress already is claimed for it.[13] Many schools, too, are beginning to discover and use such special materials as F. J. Helgren's *Metric Supplement to Mathematics,* now distributed by the Metric Association, and *Science—A Process Approach,* developed by a joint commission of the American Association for the Advancement of Science with support from the National Science Foundation and marketed by the Xerox Education Division of the Xerox Corporation.

[9] For a typical presentation of this point of view see: Pray, R. H., *op. cit.*

[10] Johnson, Donovan H., "Instructional Materials in the Mathematics Classroom," *NEA Journal* **56:** 40; May 1967.

[11] Johnson, J. T., *Official Report, American Educational Research Association,* Washington, D.C.: AERA, February 1936.

[12] Friebel, Allen C., *A Comparative Study of Achievement and Understanding of Measurement Among Students Enrolled in Traditional and Modern School Mathematics Programs.* Doctor's Dissertation. Berkeley: University of California, 1965. p. 288.

[13] *Metric Association Newsletter.* vol. 5, No. 1, February 1970. p. 3.

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Finally, most educators agree, however, that truly effective teaching of metric measurement will come only when the metric system is adopted and incorporated into the fabric of daily living. So long as it is a *second system,* teaching fallacies such as these will persist:

(1) Instruction which should begin no later than grade 3 will be postponed.
(2) Nearly all the teaching will involve association with, and conversion to, the conventional units.
(3) Many elementary schools will spend only a week or so on metric measurement—perhaps in grades 7 or 8—and never refer to it again.
(4) Metric rulers, etc., will continue to have English units "tagging along."
(5) Text materials and problems will be abstract and superficial.[14]

Because of present day superficial and varying programs, many students arrive in the shops and laboratories of the secondary schools and colleges without knowing how to use metric measurement. They are likely to find themselves quite handicapped if they work alongside others who have been introduced to the metric system. As an example of the neglect all too commonly found an industrial arts teacher writes, "Few, and in many cases none, of the industrial arts students in my classes have facility with the use of decimal equivalents of fractional-inch measurements, much less with their metric equivalents."[15] And a college teacher, complaining of the same weakness in basic instruction, reports that in a test given to 55 college students:

(a) Only 1/3 could give a reasonably good definition of the metric system.
(b) About 1/2 knew the millimeter, centimeter, and meter; 1/3 knew the liter; 1/4 were familiar with the kilogram.
(c) All said they had had very little instruction about the metric system.[16]

Educational Advantages of the Metric System

The educational advantages of the metric system pertain chiefly to two facts: (1) the simplicity and interrelatedness of metric units in contrast to the highly complex and unrelated units of conventional measurement; and (2) the simplicity of computation with whole numbers and decimals in contrast with computation with mixed numbers and fractions.

As to the first point, relative complexity, one advocate of metric measurement says:

> While any intelligent child can learn and carry in his mind the whole metric system in three lessons, and any adult can master the same in

[14] Helgren, Fred J., "The Metric System in the Elementary Grades." Arithmetic Teacher 14: 349-52; May 1967.

[15] Anderson, W. J., *Journal of Industrial Arts* 25:51; March 1966.

[16] Whitcraft, L. H., 20th Yearbook, NCTM, 1948. *op. cit.*

> one hour or less of serious study, no man ever has, and probably no man ever will, master the United States system of weights and measures.[17]

In support of such criticism it is pointed out that we have different kinds of measures bearing the same name: two kinds of pounds (Troy and avoirdupois); dry and liquid quarts; eight kinds of tons; and 56 kinds of bushels! We have measurement units with limited use such as the cord, board feet, and many others. Standard units interrelated one to another would greatly reduce the number of items to be remembered and used.

As to the computation load, Morgan and others have used a simple problem to illustrate the difference: For a cubical tank 6 ft. 9 1/2 inches on each side find: (1) the volume; (2) the liquid capacity; and (3) the weight of the full tank of water.[18]

In English units the pupil converts the tank dimensions to inches and multiplies; then divides the 541343.375 cubic inches by 1728 to get the volume of the tank in cubic feet. Likewise, he divides the 541343.375 cu.in. by 231 to get the number of gallons. Then to get the weight of the water in a full tank he multiplies the 313.277 cubic feet by 62.5 and divides by 2000 if he wishes to reduce it to tons. These are lengthy multiplications and divisions, involving some 250 numerals and replete with chances for error.

In metric units the task is much simpler. The cubic content is $2.07 \times 2.07 \times 2.07$, or 8.869743 cubic meters. With 1,000 liters in a cubic meter the liquid capacity is immediately obvious and arrived at by a shift in the decimal point: 8869.743 liters. And since the weight of a liter of water is by definition a kilogram, the tank full of water weighs 8869.743 kilograms. Only 39 numerals are used; one decimal point is moved; there are no lengthy processes; the number of "chances" for error is greatly reduced.

Nearly all teachers foresee *some* simplification of the learning process from the adoption of the metric system, and *some* economy of time that would result from it. *How much* the advantage would be and *how much time would be saved* still remain in the area of speculation and conjecture. One group that is interested in the teaching advantages of metric measurement consists of the teachers of retarded or slow learning pupils, for whom conventional tables of weights and measures and problems that involve the multiplication and division of fractions and mixed numbers are sources of extreme and constant difficulty. C. J. Arnold[19] makes no effort to predict actual saving in teaching-learning time, but says that obviously it takes twice as long to learn two systems as one, plus time to learn how to convert the units of one system into the other. Therefore, he concludes that to give adequate preparation for the use of a dual system we make the teaching task about four times as difficult as it should be.

Some have attempted to be more precise. Ratcliff reports that "educators estimate that the metric system, by eliminating fractions, would save at least

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[17] Wells, William C., *Scientific Monthly* 4:196-202; March 1917.

[18] Morgan, Joy Elmer. Quoted in 12th Yearbook, National Council of Mathematics, 1948. (For complete citation see footnote 3.)

[19] Arnold, C. J., *Minnesota Journal of Education*. 26:288 89; March 1946.

a year of time spent by children in learning arithmetic.[20] Both Martin[21] and Johnson[22] have doubled this estimate, predicting that the time an elementary child spends on arithmetic for 2 years would be saved. Johnson says that schools now spend three times as much time on fractions as on decimals, a ratio that could be reversed if the metric system were in general use.

Even more daring is the widely quoted estimate by Floyd W. Hough, chairman of the American Geophysical Study of the Metric System:

> Teachers of mathematics will agree that fully 25 percent of a child's time and the teacher's as well, could be saved in arithmetic courses if the simple interrelated metric decimal units were substituted for the English system of measurement. Such monstrosities as proper and common divisors and mixed numbers could be laid to rest with the celluloid collar and the oxcart.[23]

If the saving actually could be as great as 25 percent, or even the equivalent of the time spent by pupils and teachers for 1 year in arithmetic teaching and learning, that advantage surely would be tremendous. That metric measurement would simplify the learning task, and shorten it *to some extent,* nearly everyone agrees.

One research study which makes no claim of having proved the point, introduces an interesting hypothesis. It is a UNESCO study of the comparative achievement of the school children of 13 countries in arithmetic skills.[24] In this study the children in England and Scotland proved less proficient than those from the countries on the continent with whom they were compared. The authors, in reviewing the result, believe that the most probable explanation lies in the difference in the measurement systems used in instruction, the metric system having been *helpful* in the cultivation of arithmetic skills.

Most important of all from the standpoint of good education is the fact that in the modern world, so dependent on science and technology, the metric system has become the international language of mathematics and science. To be literate in that international language and comfortable in this technological age today's school children in the United States need to become "just as confident and fluent with metric units of measure as their counterparts in the numerous metric nations of the world." [25]

Adjustments To Be Expected

Conversion to the metric system quite obviously will have an impact on numerous aspects of education. There will be many types of necessary read-

[20] Ratcliff, J. D., *This Week,* April 16, 1944.

[21] Martin, Geo. S., *The International Metric System of Weights and Measures,* Miscellaneous Publication No. 2, Washington, D.C., U.S. Government Printing Office, September 1922.

[22] Johnson, J. T., *Seattle Times.* March 24, 1946.

[23] Quoted by Helgren, Fred J., *op. cit.* p. 349.

[24] Cited by Helgren, Fred J., *Ibid.*

[25] Anderson, J. F. and Arnold, C. J., *"Elementary Education and the 1970's"* Unpublished paper presented at the Annual Meeting of the Metric Association, Boston, December 30, 1969.

justment: some of them quite simple; some not so simple. The list which follows is by no means complete but indicates something of the range and variety of changes which must be anticipated in the nations' schools:

(1) Courses of study, especially in mathematics and in elementary and general science, will need to be revised; courses in other fields reviewed for their contributing influence.
(2) Textbooks and related teaching materials must be reviewed and revised or rewritten wherever units of measurement are involved.
(3) Teachers must be prepared—and those already teaching be retrained—to teach the new system effectively.
(4) Supervisory personnel will have to focus on this area as upon any significant change in curriculum.
(5) Classrooms, shops, and laboratories which do not have them already must be supplied with the new measuring devices: meter sticks, metric rulers, scales, etc.
(6) Maps will be introduced with metric grid lines and the distances scaled to metric units.
(7) Graph paper will be scaled by centimeters and millimeters instead of fractions of inches.
(8) Purchasing departments will use new specifications, expressed in metric terms.
(9) Boards of Education will begin to purchase land by the hectare and square meter.
(10) Even the cooks in the cafeterias will soon be readjusting their recipes in terms of metric units.

If the total transition were necessary in one quick step, the expense and disruption of programs would be enormous. If the transition is made in stages, however, over a considerable period of time, neither the costs involved nor the problems of program adjustment should be prohibitive. The experience of other nations bears out that conclusion. Existing facilities, for the most part, continue in use until time for normal replacement. Within reasonable limits the new is introduced as old items become obsolete. During the period of transition the dual system will still persist; the difference being that the metric system now becomes *the basic one*, to be learned and used, and the conventional one a supplementary one for general understanding.

The Experience of Other Nations

Several nations in the recent past have converted to metric measurement—or are now in the process of conversion: Japan, India, Great Britain, Australia, New Zealand, South Africa, and Canada. The impact of metrication on their school programs apparently has not been serious, though in several instances specific information on this phase of conversion is meager. The best reports available on the impact of metrication on the schools are coming now from Great Britain, where the process has been underway for 5

years and will not be completed until about 1975. Out of the experience reported by others come some observations and suggestions such as these:

(1) The system should be introduced into the practices of daily living, and into the schools, in appropriate stages—not all at one time.

(2) Instruction in the schools should at least keep pace with, and when possible precede, the actual application of new measures.

(3) Education must play a major role in the transition. Teachers will work with publishers on new materials. There must be articles in professional literature; short courses, conferences and workshops; experimentation with methods; curriculum study; evaluation of results.

(4) To teach a new system in terms of its relationship to an existing system is the wrong approach. Instruction must be in the *use* of the new system.

(5) A major problem in conversion is logistics. If a manufacturer adopts the metric system and his suppliers do not, he is in trouble. The same will hold in education. Instruction must be geared to teacher preparation and the availability of equipment and materials as well as to the established deadlines for nationwide adoption.

(6) Instruction in metrics should be limited to the requirements of the student for his further schooling, job needs, and daily living. This means thorough instruction in the basic metric units but selective teaching of refined and derived units with limited or special application.

An excellent brief summary of Britain's current situation has recently appeared from which the following excerpt is taken:

> The schools are essential to the changeover. Primary schools were required to adopt the metric system at the beginning of the school year last September [1969]. It had been a *second* numerical language in the other grades for generations. The students now in the primary schools will emerge thinking in metric terms. They should be grateful, because they will have lost a mental rucksack of archaic measuring units. They will have a simple, logical calculating system, which takes far less time than the imperial system to learn and will be the numerical *lingua franca* of the world.
>
> There will inevitably be a period of bilingualism. The difficulty is not in learning the metric system; it is in unlearning the imperial one. It would be unwise to encourage this bilingualism. In Britain we have had a bad example. The weathermen went over to centigrade (which they should be calling Celsius) but radio and television tried to bridge the transition by giving temperatures in both centigrade and Fahrenheit. The result is that everybody waits for the Fahrenheit figure! With this reminder we do not intend to have road signs give the mile equivalents of distances expressed in kilometers.[26]

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[26] Lord Ritchie-Calder. "Conversion to the Metric System." *Scientific American* 223:17-25; July 1970.

The report on Britain's experience outlines the major conversion stages being carried out under the coordinating auspices of a representative Metrication Board. Metric standards will become available and be applied in 1970 to construction industrial materials and to the paper, board, and printing industries. A small start is being made in metric land measurement but the major changeover there will be in 1971. Engineering and shipbuilding are in the first stages of transition and, along with the armed services, have set 1972 as their major target year. Farming also will go metric in 1972 and 1973. Footwear sizes and specifications for fabrics and fibers will be metric in 1972. In 1973 all road speeds will be posted in kilometers per hour. The Metrication Board has no legalistic "big stick." However, it "sets the signals and clears the track" for the switching. Its sanction—which is proving quite adequate—is the warning that any company, industry, or group which is not ready by the agreed upon deadline date will be left behind.

Some Representative Teaching Aids

The statement which NEA is presenting here should not—and cannot—deal with the specific materials and methods of instruction which will make the teaching of metric measurement effective. New teaching aids will be needed, however, as illustrated by the following list of basic items:

(1) Meter sticks and metric rulers.
(2) Cubes, squares, strips, and rods calibrated in metric units.
(3) The meter board, 1 centimeter in thickness and 1 meter by 10 cm, with grid lines dividing it into squares. The same board cut into squares which, when stacked, becomes a cube.
(4) Scales and balances calibrated in grams and kilograms, including the scales used in health departments.
(5) Centimeter grid paper.
(6) Maps in metric scale, showing distances and areas in metric units.
(7) Cylinders and beakers graduated in metric terms.
(8) Celsius thermometers.

Likewise there are a few basic principles in methodology which experience and logic would seem to dictate, such as:

(1) The instruction in metric measurement will need to begin when the child is first introduced to the concept of measuring an object and should continue to be taught, with growing levels of understanding and application, in every succeeding grade.
(2) Linear units of measure, the easiest to comprehend and apply, will be taught first.
(3) Instruction will need to be restricted to a single system, using metric units only and without the old units "tagging along."
(4) Teachers will first emphasize the most-used prefixes, introducing the less-used ones, such as deci- and deca-, after the basic ones are learned.

(5) Relatively greater stress will be laid on the use of decimals and less on fractions.
(6) Much practice will be needed in *using* metric standards and *estimating* in terms of metric units.

Estimated Cost of Conversion

Many variables enter into any estimate of the cost of metrication. When and how rapidly the transition occurs could greatly affect the price tag, so far as schools are concerned. If equipment and materials must be discarded prematurely, conversion could become expensive. If extensive and intensive teacher training must be done quickly, extra costs must be expected. If courses of study and curriculums must be revised under the pressure of close deadlines, funds for such work will be needed. With a more leisurely schedule, the amount varying according to one's assumption, such costs would tend to diminish or disappear altogether.

And again, what is fairly chargeable to the conversion program? How much of the curriculum revision and in-service education, for example, would go forward in any event—if not on metrication on some current educational problem? What part of the new equipment cost for metric materials would be spent on new equipment of some type no matter what system of weights and measures is in effect? What administrative costs associated with metrication are separable and identifiable and which ones would persist if conventional measurement were still in effect? And so it is with other assumptions. There are many obvious variables and very few objective data on which valid estimates can be based.

As stated already, the time schedule for conversion is a critical factor in determining probable school costs. Textbooks and semi-durable instructional materials for elementary and secondary schools are replaced on an average, 5-year cycle. Hence no appreciable *extra* expenditure for texts and semi-durable materials will be involved if the conversion schedule exceeds 5 years. For more durable equipment some additional obsolescence might be involved, though this should not be excessive. The longer the conversion period the more new metric-scaled equipment can be acquired on normal replacement schedule. The NEA Research Division estimates that to purchase essential new materials and equipment in a single year, at present cost levels, could run from 500 million to 750 million dollars. But if absorbed over a span of several years any *extra costs* should be minimal.

In the same way the cost of teacher preparation, both preservice and inservice, and any additional administrative and supervisory costs can be largely or wholly absorbed into ongoing programs if the conversion schedule extends over several years. In short, educators foresee no major cost problem for schools, if the United States decides to adopt the metric system—so long as the conversion period is long enough to make use of normal cycles and schedules.

One further fact about probable school costs should be kept in mind. Just as there *should be* no excessive additional costs associated with the conver-

sion, there *will be* no "dollar savings" to the schools—as some have implied. Any saving in "learning time" for pupils and teachers that the metric system may produce will simply release that time for other learning experiences—it will *not* reduce school costs.

The Metrication Schedule

The National Education Association does not presume to offer a specific schedule for conversion to metric standards. The educational impact will be only one of many considerations in the development of target dates and conversion deadlines. And even if the educational impact were all-controlling, who can say just what schedule of conversion would be best for the nation's schools. On some facets of this problem, however, there is wide general agreement among educators:

(1) When and if the decision is made to go metric, a "reasonable lead time" would be helpful before any significant segment of the economy makes the critical move.

(2) A dramatic kick-off date, with concerted publicity and fanfare, would help to motivate the early school efforts.

(3) An officially-established, representative board—somewhat like Britain's Metrication Board—would seem to be a helpful agency in setting up and following an orderly, coordinated schedule. Separate deadlines will be needed for various areas of conversion such as, the time for metric measurement to become effective in the sale of groceries; a deadline for metric standards in large industries such as petroleum, coal, steel, automotive, or aircraft; a deadline for fibers and fabrics, papers, and other consumer products; a deadline for metric units on road signs; the time to begin land sales by metric measurement; etc.

(4) If such a schedule is followed, over a spread of perhaps 10 years, schools will have few serious problems of adjustment as they keep pace with conversion efforts.

(5) Undue delay in starting the program—too much lead time in preparation—would be self-defeating, a retarding influence on the work in metric measurement now being launched and extended in the better schools.

Conclusions

First, by and large, the nation's teachers who have seriously considered the matter seem to concur with science and mathematics specialists that adoption of the metric system by the United States will be advantageous not only in the realms of science, technology, and international trade but also in the area of education. They are aware that problems of adjustment will arise and some added costs may have to be assumed. But there will be teaching advantages and educational economies as well.

Second, the educational impact will be most direct and extensive, but also easiest to accomplish in mathematics and science instruction; but any changeover to metric measurement will be felt in nearly all segments of the school program—for the most part a type of impact that will be welcomed as an improvement.

Third, many schools on their own initiative are beginning to extend and improve their instruction with respect to metric measurement. However, their work lacks motivation and will not become really effective so long as the metric system is a secondary and parallel system. For that reason the official adoption of the metric system by the United States would assist all such schools.

Fourth, the educational advantages of metric measurement cannot be questioned: the simplicity of the system; its interrelatedness; its use of decimals instead of fractions. Few would challenge the fact that the teaching-learning task would be eased for both teachers and pupils, especially for pupils with learning problems.

Fifth, some considerable economy would be effected in the time traditionally spent on elementary arithmetic by both teachers and pupils—time that could be better spent on other types of learning.

Sixth, while obvious problems and some added costs must be anticipated it is our considered opinion that the extent of the problems and costs has frequently been exaggerated; that many of them will be resolved and absorbed almost unnoticed once a well-planned schedule of adoption gets underway.

Finally, we believe that with a reasonable margin of lead time and a program of gradual adoption, spread over a period of perhaps 10 years, there will be few serious problems for schools and educators and none with which they are unable to cope successfully.

For these reasons the position taken by the National Education Association in 1970 and in other recent years seems eminently justified, namely, that a carefully planned effort to convert to the metric system in the United States should be put into effect as soon as possible. When this occurs educators can be relied upon to do their part, willingly and efficiently, in making the new system understandable and functional as the international numerical language of a progressive nation.

Appendix III

Report of the National Science Teachers Association at the Education Conference

Ad Hoc Committee for Study of Conversion to Metric System of Measurements September 1970

The National Science Teachers Association[1] is an organization comprised of teachers of science and others connected with any aspect of science education. Its 20,000 members include representation from elementary schools, secondary schools, colleges and universities. The association's activities include curriculum research, teacher education, issues, professional standards and practices, international programs in science education, and programs for science students. It is an affiliate of the American Association for the Advancement of Science and an associated organization of the National Education Association. The draft of this report was prepared exclusively by the Ad Hoc Committee.[2] The draft report was reviewed, revised as necessary, and approved by the Association's Board of Directors.

Section I. Classroom Activities and Instructional Procedures

A. PRESENT STATUS

1. Current Usage of the Metric System in Science Teaching

Virtually all courses in science at all grade levels teach and/or use units of measurement. The extent of usage of the metric system depends upon grade level and curriculum origin.

Elementary School Science. More recent elementary school science programs use the metric system widely for making physical measurements and in problem solving. Few, if any, elementary science programs use the imperial system exclusively, although several of them use imperial units in instances where children are more likely to comprehend the magnitude of a quantity (e.g., radius of the earth, distance to the moon) when expressed in a more familiar, imperial unit than in its metric equivalent. The use of convenient, familiar, and arbitrary units, such as the width of a floor tile or the mass of a given washer, is increasingly prevalent in elementary school science. The elementary science programs developed by curricular study groups that are national in scope tend to use metric and arbitrary units exclusively. These include: The AAAS (American Association for the Advancement of Science) Program; Elementary Science Study (ESS); The Concep-

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[2] Mr. Fred Blumenfeld, Millburn High School, Millburn, New Jersey 07041; Dr. John Maccini, Science Teaching Center, University of Maryland, College Park, Maryland 20740; Dr. Bobby J. Woodruff, Committee Chairman, Ridgewood High School, Ridgewood, New Jersey.

tually Oriented Program in Elementary Science (COPES); Science Curriculum Improvement Study (SCIS); the Minnesota Mathematics and Science Teaching Project (MINNEMAST); Elementary School Science Project; School Science Curriculum Project; and others.

Secondary School Science. Most of the more recent junior high school science programs use metric and arbitrary units exclusively, or at least predominantly, while several of the less recent ones make use of both metric and imperial units. Curricula developed by study groups that make little or no use of imperial units include: The Earth Science Curriculum Project (ESCP); Introductory Physical Science (IPS); Interaction of Matter and Energy (IME); Secondary School Science Project (Time, Space, and Matter); as well as some of those identified above under elementary school science which also produce materials for junior high school use.

Metric units are used nearly exclusively in most high school science courses in biology, physics, and chemistry. The not-so-recent descriptive biology courses require little use of units of any kind. The three course versions of the Biological Sciences Curriculum Study (BSCS) employ the metric system exclusively except in certain illustrations where a mountain height or sea depth may be expressed in feet. While three popular physics programs – those of the Physical Science Study Committee (PSSC), Project Physics, and the Engineering Concepts Curriculum Project (ECCP) – do not use the imperial system at all, the dual usage of metric and imperial units is still found in a few physics textbooks. The Ad Hoc Committee knows of no chemistry course that makes any use of imperial units of measurement. Unified science courses, which combine several sciences in a 2- or 3-year sequence and which are becoming increasingly prevalent, require a unified system of units. Because of the universal use of metric units in chemistry and their widespread use in physics, metric units are nearly always used in unified science courses.

College Science. The metric system is used predominantly in college science courses. Many courses use the metric system exclusively (e.g., chemistry). Some courses that are oriented toward application or field study (e.g., some courses in physics, engineering, geology, and oceanography use both the metric and imperial system of units for measurement, problem solving, printed teaching materials, charts, maps, graphs, etc.).

Curriculum Origin. Almost all curricula developed by funded study groups on a national scale have used metric and arbitrary units extensively, often to the complete exclusion of imperial units. Due to the widespread use of these curricula, millions of young people have been taught the essentials of the metric system during the past decade or so. There are, however, available on the market numerous science textbooks that were written by a single author or small group of authors, some of which use imperial units of measurements, often in conjunction with metric units. However, commercial publishers of individual works have in recent years been influenced more and more by the programs of national study groups, and hence, are incorporating metric units more and more and using imperial units less in their publications.

2. Trends

Metric units have been used for decades in science teaching. During the past decade or so there has been a marked trend toward an exclusive use of metric units. Although this trend has been more pronounced at the secondary level, it has also been noticeable at the elementary school level. There is also a growing tendency to provide experiences for students to learn the metric system through laboratory or practical usage rather than teaching it through formal instruction. Even in instances where both metric and imperial units are used, the trend is for students to learn to work with each system of units separately and independently without conversion of one to the other. For example, some physics courses may call upon students to determine work done in foot-pounds or in joules. Seldom are they required to convert foot-pounds to joules or *vice versa* as was the case when many of their teachers were in high school and college.

3. Advantages and Problems in Teaching and Using the Metric System

Advantages to Teaching and Using the Metric System. Compared with the imperial system of units, the metric system is relatively easy to teach for several reasons:

(1) Because the metric system is based on tens, it is easier for students to understand, remember, and convert the various size units of the same quantity than is the case with the imperial system of units. For example, the relationships among millimeters, centimeters, meters, and kilometers are far simpler than the relationships among inches, feet, yards, and miles.

(2) Unit conversions and calculations are far simpler and more efficient for students to perform. Because calculations can be done with decimal fractions rather than common fractions, students are generally more accurate in their handling of calculations in the metric system than in the imperial system. For the same reasons, the metric system lends itself much more readily to the use of the slide rule than does the imperial system. For example, students generally can calculate quicker and with less error the volume of a rectangular solid that is 20.9 mm × 9.05 cm × 0.52 m than one that is 10 in × (2 ft, 7 in) × (1 yd, 2 ft, 5 in).

(3) The entire system of metric units is more coherent and easier to comprehend than the imperial system. Metric units of mass and volume are related to a linear dimension of space, whereas there are no defined relationships among a slug (or pound), a gallon, and a yard or among any of their sub-units.

(4) Students find that measurements are more easily made in metric units than in imperial units. It is much easier, and generally more accurate, to estimate by interpolation a point that lies three-fourths the distance between 8.7 and 8.8 cm than one that lies three-fourths between 3-1/4 in and 3-3/8 in. Also, since the graduation marks on a yardstick or foot ruler represent common fractions with different denominators, errors in reading the graduations are common.

(5) The similarity between the metric system and United States coinage facilitates the teaching and learning of the metric system.

In addition to the above factors, which facilitate the teaching and learning of the metric system, the system has other advantages in the science classroom:

(6) Because metric measuring instruments are often calibrated in smaller units or sub-units than are those marked in imperial units, measurements made in the metric system are frequently more precise. This is generally true of linear, volumetric, and mass measurements, but often is not true of temperature measurements.

(7) Because calculations and unit conversions are easier and faster with quantities expressed in metric units rather than imperial units, mathematical tasks interfere less with the learning of science when the metric system is used than when the imperial system is used.

Problems of Teaching and Using the Metric System. The chief, and only significant, difficulty in teaching and using metric units in the classroom is that students tend to regard the metric system as a "second" language to be learned and used for specific purpose. By the time most students become acquainted with the metric system, they are so habituated in their use of thinking with the imperial system that it is often difficult for them to make the transition to metric units. Even when they become competent and facile in using the metric system in calculations and ordinary measurements, they find it difficult to comprehend the magnitude of some metric units. For instance, the volume of a liter is often understood only when it is related to a quart. A temperature of 98.6 °F is understood (or felt intuitively) more readily than its equivalent of 37 °C. A body weight of 150 pounds is more meaningful to students than the same weight expressed as 666 newtons (or 68 kilogram-force units). After considerable experience with using metric units of space in the magnitude range of classroom dimensions, a distance of 50 miles is still more comprehensible to students than its approximate equivalent of 80 kilometers. Most students do not acquire sufficient experience with the metric system in science classrooms alone, even those in which metric units are used exclusively, to enable them to think in terms of metric units. Moreover, there is little incentive for them to do so, for when they leave the science classroom, they must, in all other aspects of ordinary living, use and think in terms of imperial units.

Problems of Learning the Metric System. The problems that students presently encounter in learning the metric system in this country are probably the same as the present problems of teaching and using the metric system in our science classes (see above). Apparently, little is known about the problems that students in this country have in learning the metric system or about the best ways of teaching and learning the metric system. (The committee understands that Dr. Arthur H. Livermore and the AAAS Commission on Science Education have, over about a 5-year period, studied the metric learning problems of elementary school children. The committee is, however, unfamiliar with the findings of the studies.)

The ERIC Clearinghouse for Science and Mathematics Education of the Ohio State University recently completed a cursory search of the literature concerning teaching and learning of the metric system. Eleven articles, a pamphlet, and two dissertations since 1944 represent a surprisingly small body of research from this retrieval system. (Bibliography is appended to this report.) Dr. Stanley Helgerson, Director of ERIC, reports that a complete search on this topic would not likely contribute many more sources of information. Therefore, governmental and private agencies should lend early support to research efforts related to means by which metrication can be best accomplished at all grade levels and for preservice and inservice workshops.

Dual Measuring Systems. Except for the possible advantage of understanding the nature of measuring systems in general by comparison, it is impossible to conceive of any advantage in the use of more than one measurement system in science teaching, provided the system that is used is adequate for the purpose for which it is required. The metric system is entirely adequate for all purposes of science teaching (and probably for every purpose in this country), while the imperial system of measurements is inadequate in many ways. The only justification for the use of dual systems of measurements in science teaching—and the justification is a weak one—is the continued use of imperial units in this country outside the classroom.

Summary. So long as the imperial system of units is the primary system of measurements in this country and so long as the utility of the metric system is, in the views of students, confined to science classrooms and laboratories, the metric system of units is, and will continue to be, difficult for students to learn and use. If and when metric units are used primarily or exclusively in this country, there is no reason to believe that any significant difficulties in using the metric system in science instruction will persist. There is nothing about the metric system of measurements *per se* that makes it difficult to learn except for those attributes that are inherent in any system of measurement. Because of the several advantages that the metric system has over the imperial system, there is good reason to believe that it will be easier to teach, to learn and to use than our present system of measurements.

B. POSSIBLE FUTURE EFFECTS

Note: It is to be emphasized that this report deals with the impact of measurement system conversion in science education, not with any other area of education.

1. Effects of Increased Usage Without National Program

Assuming that there is no national program to increase the use of the metric system in the United States, the continued increasing worldwide and domestic use of the metric system should have no deleterious effects on science education beyond those now existent. Any such increase should accelerate the trend in science teaching toward increased use of the metric system in the classroom and in textbooks and other instructional aids and may decrease somewhat the time spent in teaching the metric system. How-

ever, without a national policy for a complete conversion, such increased use of the metric system would do very little to reduce the present difficulties that stem from the fact that for students the imperial system is a "native" language while the metric system is a "second" language that often is not taken seriously. Present problems in the teaching and use of the metric system in science classes can be solved only by a commitment, a policy, and a planned program of converting to the metric system in all sectors of national life.

2. Problems and Costs of Conversion Through a National Program

Advantages and Disadvantages. A nationally planned conversion from the imperial to the metric system of measurements would entail no long-term disadvantages for science teaching. The only disadvantages would be those related to the costs and practical difficulties involved in the conversion process itself. Any short-term disadvantages would be outweighed by far by the long-term advantages that would accrue to the teaching of science by a national conversion to the metric system.

Teacher Training. Some training in the use of the metric system would be necessary for some science teachers, although the need would be minimal compared with the training requirements of other teachers or persons in most other occupations. It is expected that the need would be greatest among teachers of elementary science, especially teachers of self-contained classrooms who are not science teaching specialists. However, these teachers would need training in the metric system for several other curriculum areas. The need for training of secondary school science teachers would be minimal and would constitute no problem of any significance. Among secondary science teachers, a minority of junior high school teachers and a few biology and earth science teachers may need some refresher training in the metric system. It is anticipated that few, if any, teachers of chemistry or physics would require such training.

Probably every school district has within its professional staff a sufficient number of science teachers who are qualified to provide the training required by all other teachers in the school system, or at least all science teachers in need of training. The problem of providing such training will undoubtedly vary widely from large city school systems to small school systems in some rural districts. Most school systems, however, have some provisions for the inservice training of teachers, provisions which in most cases should be adequate for the training of teachers in the metric system.

Leadership Training. There will probably be a need for leadership training for the science teachers and others who provide instruction for local inservice groups. Such leadership training could be provided by state departments of education, on a regional basis, or by colleges and universities through federal grants. Part of the leadership training might be offered as part of existing programs for science teachers conducted by colleges and universities with federal funds. Leadership training of no more than a week should be adequate.

Type of Training Needed. The type of training that would be required de-

pends considerably on the needs of teachers of the various sciences and grade levels. Generally, secondary science teachers are likely to need little more than refresher instruction, while many elementary science teachers will likely need basic and more thorough training.

Little is known about the effectiveness of various methods of teaching the metric system to anyone—teachers or students. There is a great need for a program of research to determine the best ways of teaching the metric system and ways of evaluating understanding and performance in the use of it. In the absence of research findings, it is believed that the most effective method for adults is to provide a concentrated period of time in which they have both extensive and intensive experience in the practical use of the metric system in a wide variety of physical measurements and in problem solving. For those who are already familiar with the imperial system, conversion from metric units to imperial units and *vice versa* should be emphasized no more than is necessary for the establishment of equivalence benchmarks (e.g., that a foot is approximately equal to 30 cm, that a kilogram-force unit is about 2.2 pounds, or that 5 miles is about the same as 8 kilometers).

Cost Considerations. Most science classrooms and laboratories especially those in secondary schools, are already equipped with metric instruments. Measuring devices currently in use and calibrated in imperial units could undoubtedly be replaced with metric ones on a normal replacement schedule within a period of 10 years or less. Such instruments consist of items no more expensive than yardsticks and spring balances calibrated in pounds. In some instances, metric calibrations could be added to existing equipment until such time as it can be replaced. Over a 10-year period, or less, there should be little or no costs involved, beyond normal replacement costs, in equipping laboratories completely with metric instruments.

Some textbooks, films, and other teaching materials would require modification as a result of conversion to the metric system. Practically all of such modifications would be the responsibility of commercial producers. The average usable period of most textbooks is from about 3 to 6 years. Hence schools should incur no costs above normal expenditures as a result of metric conversion over a period of 10 years or less, provided revised textbooks are available from publishers during the first half of the 10-year period. This seems not to be a serious problem since most publishers of educational materials revise textbooks approximately every 5 years or so. The life expectancy of films is longer than that of textbooks. But again, most science films that involve measurements at all already use the metric system. Many school systems do not own, but rather rent, films; hence, those schools would entail no costs as a result of unit conversion. Films in libraries owned by large school districts, counties, or regional educational units have a useful life expectancy that is probably under 10 years. Thus, large educational units should be required to bear only very small costs over a 10-year period in replacing the few films that are now geared to the imperial system of units.

Curriculum Changes. Since science instruction is already based far more on metric units than on imperial units, no major changes in curricula should be required as a result of conversion from imperial to metric units. Probably

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the only change that would be needed would be the placing of greater emphasis on the use of metric measurements in elementary school science than is now the case.

3. Educational Advantages of Measuring System Conversion

The educational advantages of the metric system are essentially the advantages of the general use of the metric system (see A-3 above). The simplicity, efficiency, and coherence of the metric system make it easier than the imperial system to teach and for students to learn and to use in making physical measurements and solving problems. As noted above, measurements made in the science laboratory using metric units are often more precise than those made in imperial units. In addition, the relative simplicity of metric unit conversions and calculations causes mathematical problems to distract less from the teaching and learning of science than is the case with imperial units. The adoption of metric measurements for general usage would greatly benefit science education, particularly at the secondary level, by freeing science teachers of most of the time they must now spend providing basic instruction in the metric system, or in remedial efforts related to difficulties inherent in imperial unit calculations, and by allowing them to devote more time to the teaching of science. Furthermore, familiarity with the metric system extends pupils' range of communication; they can read, with better understanding, material from other countries and, eventually, exchange data with colleagues elsewhere with greater ease.

4. Proposed Plans for Conversion to Metric System

Proposed Timetable. From the standpoint of science education, the process of conversion from the imperial system to the metric system should be accomplished at the earliest and in the shortest feasible time. The schedule proposed below is believed to be a reasonable one so far as education in science is concerned. It is recognized, however, that the best results will be obtained if conversion efforts in science education are coordinated and are consistent with those in other areas of education.

Proposed, 10-Year Conversion Schedule

Year	*Proposed Plans*
0–2	Planning, training, support for research, and other preparations.
3–7	Grades 7–12: metric system to be taught and used exclusively.
	Grades K–6: metric system taught as a "first language," imperial system taught as a "second language."
8–10	Metric system used exclusively in all elementary and secondary education.

The 2-year period of planning, teacher training, and other advanced preparation should be sufficient for teachers of science. During this 2-year period of planning and preparation at the local and state level, colleges and universities that prepare teachers of science would have a year or more to prepare preservice teachers in the use of the metric system, thus ensuring that all teachers entering the profession during the conversion period and thereafter would be thoroughly conversant with the metric system. Research

related to teaching and learning the metric system should be encouraged and supported prior to, or at least during this period.

At the beginning of the third year, the exclusive use of the metric system in the secondary schools (grades 7-12) should be feasible. This plan would ensure that students who graduate from high school at the end of the seventh year and afterwards, when the conversion is making headway in the nation at large, would have a working knowledge of common units of the metric system. Also at the beginning of year three, the metric system should be used as the measuring system of primary usage in grades below grade 7. At the same time, only those aspects of the imperial system that are likely to be needed by students for the duration of the conversion process should be taught as a "second language." Also beginning with year three, it should be possible in schools that employ science teaching specialists in elementary schools for the science teaching specialists to deal exclusively with the metric system, leaving the teaching of the imperial system to the regular classroom teacher.

Colleges should strive to meet the above conversion timetable in their science offerings, especially those offered for general education. It is possible that some of the more specialized courses for which there is a limited option of textbooks may have to await the availability of textbooks that substitute metric for imperial units.

Leadership and Coordination. In the interest of an orderly and minimally frustrating conversion of measuring systems, the major leadership and coordination efforts for the change should come from the national level. So far as education is concerned, it would be desirable that national planning be carried out in consultation and in conjunction with state departments of education and with professional organizations at the national level. State departments of education, among other possible functions, should provide leadership in developing plans with local school districts for the inservice training of teachers in metric usage and should ensure compliance by local districts with state and national plans and schedules. Local school districts should develop and carry out plans, consistent with state and national plans, for teacher training, for making any needed curriculum changes as a result of the conversion to metric system, and for replacing laboratory equipment and other teaching materials over a scheduled period of time.

5. Information Concerning Metrication Plans or Experiences of Other Countries

The Ad Hoc Committee has no knowledge of the metrication plans or experiences of other countries, except for the plans announced by Great Britain in "Going Metric: The First Five Years," the first report of Britain's Metrication Board (London: Her Majesty's Stationery Office, 1970). The plans reported therein are general, not specific. The recommendations and proposals of this Ad Hoc Committee appear to be consistent with the general plans announced by the Metrication Board for Great Britain.

C. POSITION AND OPINIONS

1. Association's Official Position

In March 1969, the National Science Teachers Association in annual convention overwhelmingly adopted the following resolution as its official position on the issue of converting to the metric system of measurements.

> The National Science Teachers Association applauds the authorization by Congress in July, 1968 of a study of the advantages and disadvantages of converting to the metric system. We recognize the need for an objective evaluation of all aspects of the conversion process and for sound guidance in planning and implementing those changes essential for a more extensive use of the metric system in the United States.
>
> The simplicity and efficiency of the metric system have long been evident to scientists and educators. The desirability of a worldwide uniform system of measurement is obvious; approximately 90 percent of the earth's population resides in nations committed to the metric system. For the United States, conversion appears necessary and inevitable. The Association therefore strongly urges that the metric system and its language be incorporated as an integral part of the education of children at all levels of their schooling.

2. Other Opinions or Suggestions

a. A liaison body at the national level should assist in coordinating the conversion plans of education and those of educational testing services, textbook publishers, and producers of laboratory equipment and supplies, films, and other teaching materials.

b. Plans for conversion to the metric system by educational institutions should proceed in a careful, orderly, and deliberate manner. It would be unfortunate if individual schools and school systems developed uncoordinated plans in response to increased usage of metric measurements without a national policy and an established timetable. It would be confusing to the many students who transfer between school districts; it would frustrate the planning of publishers and other producers of educational materials; and the lack of a national policy and timetable would perhaps engender resistance from some parent groups and some teachers who are ignorant of the metric system or who remain unconvinced of the need for change. The chaotic situation that would likely arise would be far less desirable than acceptance and compliance that would accompany a universal imperative.

c. Advancing the schedule of conversion in education ahead of the schedule set by industry, transportation, communication, and other sectors would have the advantage of preparing students to assist in the education of their parents, who will be the most immediate and confused consumers when the conversion begins on a national scale.

d. The Ad Hoc Committee and the Board of Directors of the National Science Teachers Association wish to reiterate the position stated in the

above resolution (paragraph C-1). We strongly urge that the metric system and its language be incorporated as an integral part of the education of children at all levels of their schooling. We believe this goal can best be realized within the context of a complete conversion to the metric system in all sectors of national life.

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Some Education Statistics

The Magnitude of the American Educational Establishment

1960—1970

This year there are more than sixty-two million Americans engaged full-time as students, teachers, or administrators in the nation's educational enterprise. During the past decade, the number of students has increased by thirteen million, with the bulk going into public schools, two-year colleges, and universities. Costs have risen by 160 per cent to $70-billion. There are a million new teachers, more than half again as many administrators as there were ten years ago, but fewer school districts and institutions, reductions brought about by school district consolidations and the use of larger buildings. The breakdown is given here:

	1960-61	*1970-71*
Institutions		
Elementary	95,200	82,852
Secondary	26,500	30,810
Universities, colleges, and junior colleges	2,000	2,525
Total	123,700	116,187
School Districts	40,520	19,169
Students		
Pupils in elementary schools (kindergarten through eighth grade)		
Public schools	27,692,000	32,400,000
Nonpublic (private and parochial)	4,800,000	4,200,000
Total	32,492,000	36,600,000
Secondary school students		
Public high schools	8,589,000	13,600,000
Nonpublic	1,100,000	1,400,000
Total	9,689,000	15,000,000
College and university full- and part-time students enrolled for credit toward degrees		
Public institutions	2,115,893	5,313,000
Nonpublic	1,466,833	2,064,000
Total	3,582,726	7,377,000
Total students enrolled	45,763,726	58,977,000
Teachers		
Elementary school teachers		
Public	858,000	1,084,000
Nonpublic	133,000	148,000
Secondary school teachers		
Public	550,000	928,000
Nonpublic	59,000	85,000
College and university teachers		
Public	241,000	569,000
Nonpublic	197,300	264,100
Total	2,038,300	3,078,100

	1960-61	*1970-71*
Administrators and Supervisors		
Superintendents of schools	13,012	12,917
Principals and supervisors	83,292	121,005
College and university presidents	2,000	2,525
Other college administrative and service staff	46,000	88,000
Total	144,304	224,447
Board Members		
Local school board members	166,571	102,743
State board members	780	500
College and university trustees	35,000	25,000
Total	202,351	128,243
Cost (in billions)		
Current expenditures and interest		
Elementary and secondary schools		
Public	$14.1	$35.6
Nonpublic	1.9	4.1
Higher		
Public	3.3	13.1
Nonpublic	2.7	8.4
Capital outlay		
Elementary and secondary schools		
Public	$2.9	$5.1
Nonpublic	0.4	0.6
Higher		
Public	0.9	2.6
Nonpublic	0.8	0.5
Total	$27.0	$70.0

Figures based on latest available estimates from the U.S. Office of Education and the National Education Association.

SR/SEPTEMBER 19, 1970

Table 1. Number of public school systems and number of pupils enrolled, by size of system; United States, 1966–67

Enrollment of pupils, October 1966	School systems		Pupils enrolled	
	Number	Percent	Number (thousands)	Percent
Total	23,390	100.0	43,842	100.0
25,000 or more	170	0.7	12,590	28.7
12,000 to 24,999	350	1.5	5,730	13.1
6,000 to 11,999	880	3.8	7,293	16.6
3,000 to 5,999	1,726	7.4	7,178	16.4
1,800 to 2,999	1,819	7.8	4,251	9.7
1,200 to 1,799	1,636	7.0	2,416	5.5
600 to 1,199	2,838	12.1	2,437	5.6
300 to 599	2,723	11.6	1,185	2.7
150 to 299	2,091	8.9	459	1.0
50 to 149	2,230	9.5	209	0.5
15 to 49	2,673	11.4	71	0.2
1 to 14	2,368	10.2	22	0.1
None*	1,868	8.0		

* Systems not operating schools.

Digest, p. 42, table 57.

It seems useful to group these data as follows, to demonstrate the large number of small school systems which may be hard to reach for teacher training and curriculum innovation.

	School systems (Percent)	*Pupils enrolled (Percent)*
6,000 or more	6.0	58.4
600 to 5,999	34.3	37.2
Less than 600	51.7	4.2

Table 2. Private vocational schools and students, 1966*

Category	Schools	Students
Trade and technical	3,000	835,710
Business	1,300	439,500
Cosmetology and barber	2,771	288,346

* A. Harvey Belitsky, *Private Vocational Schools and Their Students*, Schenkman, Cambridge, Mass. (1970), page 9.

(Also A. Harvey Belitsky, "Private Vocational Schools, Their Emerging Role in Postsecondary Education," a staff paper of the W. E. Upjohn Institute for Employment Research [June 1970.])

Appendix V

Curriculum Changes for School Mathematics

A recommendation by: S. Sternberg, Professor of Mathematics, Harvard University

From a passive point of view, the transition to the metric system can have an effect on education similar to the effect on the economy. A certain amount of retraining of the teachers will be necessary to help them adjust to the new system, analogous to retooling industry. The analogue of consumer resistance will not be present, since children have no built-in preference for the foot-pound system. On the contrary, the simpler manipulative rules of the metric system will make the metric system more attractive to children and easier for them to learn. As most current teacher training involves some exposure to the metric system, teacher resistance can also be minimized through a gradual shift in emphasis in teacher training institutions.

However, if imaginative advantage is taken, then conversion to the metric system can be used as a vehicle for instituting substantial improvements in the mathematics curriculum. These are:

- early introduction of decimal fractions, with corresponding reinforcement of the place value system;
- an increased connection between the geometry and the arithmetic portions of the curriculum;
- a considerable downplay of inessential skills in manipulation of fractions;
- ease of introduction of exponents and "scientific notation";
- elimination of substantial amounts of time wasted in the junior high school on "percent problems."

We now discuss these various points in detail. At present, children have no prior intuitive experience with the place value system and no reinforcement other than the use of money. With the metric system, children can be exposed to primitive experiences (not verbalized or made explicit) which bear directly on the place value system. As early as the 1st grade, they can be given experience in measurement of weight, length, area and volume (liquid) in which they will automatically convert in units of 10. Much of this experience can precede the standard introduction of place values via counting, and it can provide both prior intuition and reinforcement. As early as the 2d grade, decimal fractions to two places can be introduced.[1] A typical lesson might have the children guess at the lengths of various objects, first to guess the length to the nearest centimeter and then to the nearest millimeter; all this taking the decimeter as the natural unit of length for children. This lesson simultaneously introduces decimals to two places and, when

[1] Professor Andrew M. Gleason of Harvard University has told us of his success in teaching decimal fractions to second graders.

everything is expressed in terms of millimeters, numbers to three digits. In the 2d and 3d grades, addition and subtraction of three digit numbers, and decimal fractions to second order can be taught together. The decimal equivalents of 1/2, 1/4, and 1/5 can be introduced, by area counting primarily, but also by length and money. By the 4th grade, the exponential notation can be introduced, again reinforced by the fact that the units are changed dually to the numbers. Some suggestions have recently been made for linguistic and notational changes in this area,[2] changes which are already implemented in part in computer programming.

In the current curriculum there is too little emphasis on geometry in the primary grades, and especially the measurement aspects of geometry. This is principally due to a reluctance on the part of educators to take time away from the teaching of basic arithmetical skills. With the metric system, the geometry curriculum can be easily used to supplement and reinforce the teaching of the arithmetical skills. There would be more of an emphasis on the metric and coordinate aspects of geometry, and geometry and arithmetic would be much more closely coordinated. The measurement of area is much more convenient and instructive in the metric system.

In the present curriculum, a considerable amount of time is spent in developing skills in the manipulation of fractions. For most students much of this is a waste of time. Many students do not develop any feeling for the relative size of rational numbers when presented in the form of fractions. When presented in decimal form, they acquire more meaning. In practice, one has very little use for learning the rule for addition of two complicated fractions: it only becomes useful when the student comes to add two rational functions in high school algebra. It should therefore not be emphasized in the elementary school curriculum, and it might even be eliminated. The major emphasis on teaching algorithms for adding fractions should come just before the corresponding algorithms are taught in the high school algebra course. In elementary school, all fractions should be converted to decimals, and the addition and subtraction operations all done on decimals. Conversion to the metric system will help give a push in this direction, not only by enforcing the study of decimals earlier in the curriculum, but by tending to remove the last vestiges of the need to study the algorithm of fractions.

Practically 6 months of instruction time in the 6th, 7th, and 8th grades are currently devoted to the notion of "percent." All this time would become unnecessary if decimals are introduced from the start, and if all fractions are

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[2] Richard P. Feynman, a letter to the editor of *Scientific American*, November 1970, p. 6; M. Danloux-Dumesnil, *The Metric System: A Critical Study of its Principles and Practice*, University of London, The Athlone Press (1969), pp. 148 ff.

The urgent notational problem addressed in these papers has existed since Simon Stevin gave us the decimal point in 1585. If one of these suggestions could be even partially implemented in elementary school mathematics, it would greatly aid in the teaching of "scientific notation," the laws of exponents, and the appreciation of the relative size of numbers.

There is much to be said for the general use of these notations, for they would simplify measurement language by eliminating the customary Greek-and Latin-derived prefixes which are now recommended only for every third power of ten.

automatically written in decimal form. By the downgrading of fractions and the elimination of the time spent on "percent," a year to a year-and-a-half can be cut out of the current curriculum. This would make room for innovative introduction of materials into the elementary school curriculum, primarily in the direction of probability and statistics and coordinate geometry.

Inservice Training Programs

a. Outline of an Inservice Training Program for a County-Wide School District

Gerard J. Putz, Science Consultant, Macomb Intermediate School District, Mount Clemens, Michigan

Macomb Intermediate School District provides central services to 21 local school districts in the county and coordinates academic and administrative activities among them. Its academic divisions are special education, instruction, vocational, data processing, and research. Other intermediate school districts in the state of Michigan may provide more or less in the way of academic services and more or less in the way of administrative and other coordination functions, including centralized purchasing and payroll and bus transport of children.

The proposal outlined below is based upon successful experience in this District, including the preparation of secondary school teachers in the use of computers and a workshop on safety for secondary science teachers.

A discussion of teacher training should take the needs of children as well as the needs of the teachers into consideration at three different levels of instruction:

A. Early Elementary (K-3)
B. Upper Elementary and Secondary Schools (4-12)
C. Adult Community

The greatest need for training of teachers will be at the early elementary grades (K-3) and the greatest need for retraining of students will be for students (grades 4-12) and adults who are already familiar with the customary system.

Elementary school teachers will require the most intensive inservice training. The training should be similar to that which we hope they will use with their students as teachers generally "teach as they are taught." We should consider some basic guidelines concerning measurement before going on. To begin with, measurement should not and really *cannot* be "taught" through a series of planned lessons. Learning to measure (especially in a relatively unfamiliar system) is a *gradual* process related to each child's *experiences*. Until a child has had the opportunity to experience in concrete, comparative terms what a gram and a kilogram, or a centimeter and a meter are, the term "five centimeters plus seven centimeters" is meaningless to him. Again, it is much like learning a new language. We have discovered that we cannot teach a new language (which the metric system really is) by teaching the vocabulary and grammar of this language. The most effective

way to learn the new language is to *use* it in meaningful, everyday oral expressions. So too with the metric language, children will learn it best if it is not "taught" but experienced and used in some activity in the context of situations in which a child is actively involved (sewing, cooking, caring for animals, racing "hot wheels," comparing heights of roommates, etc.). The training of teachers should reflect this principle. This gradual experimental process is the most effective way to unlearn an old system and relearn a new system.

In the judgment of the science, mathematics, and vocational teachers and consultants of this district, secondary school teachers of these subjects are already quite familiar with the metric system. They need very little, if any, special inservice training, other than challenging and interesting investigations to demonstrate the advantages of the metric system. The metric system is the *normal* mode of instruction for 95 percent of our senior high math and science classes.

If any inservice training were to be conducted for the secondary school teachers, I would recommend a half-day "awareness" workshop dramatically emphasizing the advantages and differences of the metric system. The six basic units of the International System would be emphasized together with the unitary nature of the derived SI units, and interesting and imaginative investigations would be developed to illustrate the calculation of the derived units.

For the secondary school teachers (grades 7-12) this awareness workshop could be conducted at the Macomb Intermediate School District for the approximately 70 department chairmen in Macomb County who could, in turn, conduct similar inservice training for their respective staff.

Students majoring in secondary science and mathematics will need very little assistance, for the metric system is well covered and is the standard system used in measurements and calculations. However, the nonscience majors do not focus in this way on the metric system; they will be familiar only with the English system and be in need of additional training. We believe that for the nonscience majors and the nonscience teachers the most important factor that will facilitate their learning a new system of measurement will be time and not any one-shot concentrated effort. Like learning a new language, it will be important that they are given every opportunity to *use* the new "metric language" in their everyday *experiences*—both personal and vicarious (T.V., news media, etc.). If they are exposed to the new system often enough, if they realize the benefits and advantages of the new system and if a need to use the new system is established, then they will *gradually* develop an increasing facility with the metric system without any special intensive training.

Inservice training would be most effective if conducted before school opens for the fall term. Five to eight 2-hour sessions would be conducted by the principal or a master teacher. The Intermediate School District would bear the responsibility for training these instructors at a county-wide institute or workshop. This training could also be conducted over national educational TV, but we believe a "hands-on-experience" approach would be a more effective mode of instruction.

Adult education directors and community school directors believe that a national THINK METRIC campaign would be more effective and successful than any special class they could organize on the subject.

b. Outline of an Inservice Training Program Using Television in Part

Annie Sue Brown, Visiting Associate Professor of Education, University of Georgia, Athens, Georgia

This proposal is based upon experience with inservice training programs using television in part carried out in Atlanta where the author served as science supervisor. It is an extrapolation of the programs produced there for the introduction of the AAAS science curriculum, *Science—A Process Approach*, and draws to some extent upon Atlanta's experience with it.

The outline offered here is incomplete and must be completed locally, taking local conditions into account. The videotapes of experimental classrooms should be made locally using the inexpensive and unobtrusive portable cameras and recorders which have come to the market in the last few years.

The television inservice training program consists of an intensive period of television lessons together with some face-to-face meetings with an instructor. These might be followed by a sequence of monthly TV lessons comprising videotapes of further successful teaching situations, or by a more extensive course in teaching elementary mathematics. The intensive period would consist of four to six broadcasts and one or two face-to-face meetings over a period of 2 weeks. If time were available, it could precede the opening of school in September; but otherwise it would be appropriate to secure released time by dismissing classes an hour early on 6 to 8 days during the first 2 weeks of the term. In either case, the event should be promoted as the start of metrication in the local school system.

The initial broadcasts should be based upon successful teaching experiments carried out during the preceding school year to discover students' reactions and the ways in which they best learn metric units and measurement. These trials should be under the direction of the supervisor of elementary mathematics and science, and experiments should be made at all grade levels and by teachers of various degrees of experience. Four to six videotapes of 20-30 minutes duration each should be edited from these experiments. They would constitute the TV portion of the intensive period of inservice training. Each tape should be accompanied by program notes distributed in advance, together with instructions for a sequence of measurement activities to be performed by the teachers immediately after the broadcast. The exercises should not take more than an hour.[1]

[1] The instructions should say what measuring devices to bring to the viewing area and what objects might be brought to be measured. Typical measurement activities might include: measure your own "vital" dimensions, measure straight and curved lengths, regular and irregular areas and volumes, various objects in and around the classroom, etc.

This portion of the inservice training program can be completed by the teachers alone or in small groups, and an instructor need not be present. However, the TV sessions should be accompanied by perhaps two face-to-face meetings between groups of about 20 teachers and an instructor who is a member of the inservice training team, preferably a teacher who took part in the lessons which were videotaped. These face-to-face sessions could be devoted to clarification, other teaching strategies, and further measurement activities appropriate for the grades that the teachers are teaching.

The intensive portion of the program must include lessons and activities on the measurement of length, area, volume, capacity, mass, and temperature. In addition to classroom videotapes, at least one broadcast ought to be devoted to the description and use of the apparatus supplied to the schools and to information about inexpensive things that teachers can buy or find or make themselves to use in their own classrooms.

This initial period should provide the knowledge base for teaching metric units. The inservice training program might terminate here, or it might continue for the rest of the year in one of several different ways. For example:

(a) A broadcast each month of additional excerpts from lessons videotaped during the current year, demonstrating additional ways of teaching and learning measurement; together with one or two face-to-face meetings with an instructor. The broadcasts might be in the same format—a 20-30 minute videotape together with program notes and some new activities for the teachers to perform during the rest of the hour.

(b) A more intensive program of lessons in the same format, which might lead to academic credit for mathematics teaching. As we have suggested above, the intellectual and skills content of the metric system is small, and familiarity with it can be achieved only by usage. Accordingly, an inservice training program on the metric system alone can hardly justify the award of any substantial amount of credit. However, the curriculum modifications in elementary mathematics which should accompany metric conversion warrant considerable attention, and they would require teachers to learn new teaching skills. These subjects include the introduction of decimal fractions at the second grade level, measurement activities of all kinds for grades 2-4, the estimation of number and of various physical quantities, limits of accuracy and the meaning of significant figures, place value, approximate calculations, and the exponential notation. An inservice course of this dimension would easily comprise 3 hours of academic credit. (If academic credit or credit toward a salary increment is to be awarded, it may be necessary to prepare performance objectives and measures of competence. Reading material might be made available on the history of the metric system and on the experiences of others in going metric and in teaching relatively "advanced" concepts to relatively young children.)

The entire program of inservice training should be developed under the direct supervision of the person responsible for elementary curriculum in mathematics and science. The team would include technical people, of course, and the teachers of trial classes and other resource people, according to local conditions.

The inservice training program should be attended by teachers who teach in self-contained classrooms and by mathematics and science specialists. Teachers who teach with mathematics and science specialists would profit from some parts of the program, if not all of it; and it would ease organizational problems if all elementary teachers in the system were to participate in at least the intensive portion. The program should be designed to take their various needs into account.

A Plan for Implementing an Inservice Teacher Training Program for Teaching the Metric System of Measurement

1. Establish the need for using the metric system. (This may be part of the THINK METRIC campaign.)

    (a) Articles in local papers
    (b) Comments on local, state, and national television programs
    (c) P.T.A. programs
    (d) Letters to teachers and parents.

2. Secure the approval and encouragement of school authorities.
3. Identify and prepare the instructors and resource persons; and conduct teaching experiments and prepare videotapes of them. Edit the videotapes to make about six 20-30 minute presentations.
4. Arrange compensation for successful completion of the course. Give teachers one or more of—

    (a) Increment credit (clear with school personnel office that the course will be recognized for credit).
    (b) College or university credit (check with college and university concerning the time requirements and performance objectives and measures).
    (c) Money.
    (d) The pleasure of accomplishment and public service.

5. Announce the offering of the concentrated course and the academic year follow-up. Include in the announcement the structure of the presentation.
6. Organize classes according to the number of teachers involved, where they teach, the assignment of instructors, and other details of administration.
7. Teach the program and evaluate teachers' responses.
8. Make changes based upon evaluations.
9. Repeat the course during the summer and try some variations.

    (a) Try spending more time in class each day in order to cover the material in 1 week.
    (b) Consider broadcasting on Saturday mornings instead of after school, if local people desire it.

c. Recommendation for a Workshop-Based Teacher Training Program to Introduce the Metric System

Adeline Naiman, Elementary Science Study,[2] Education Development Center, Newton, Massachusetts

In order to get teachers to unlearn the English system and "think metric," I believe that a slow, steady workshop program is needed over a long time—half a day a week for a school year would not be too much. Alternatively, a week-long saturation workshop could be carried out, but this is less likely of success. A third possibility is the one we have used here at the Elementary Science Study (ESS)— a 4-week summer institute for six teams of five teachers/science supervisors from six regions of the U.S. These teams have come here, spent day and night with ESS staff in workshops and discussions and then gone back to their home districts to run 2-week workshops for teachers in their own school systems with follow-up throughout the year. ESS staff have been available to help with the 2-week workshops and for consultation and visits during the year.

This last model might well be modified to fit the needs of the metrication program. Key teachers or mathematics/science specialists could be brought to summer institutes and could then run workshops for their colleagues at home. ESS has also run 1-week workshops during the school year as an introduction to our materials, and this is an alternative model.

The essential component of a workshop of this kind is material that stimulates the participants and gives them something to take home and teach to other teachers or to their students. "Learning by doing" is the precept. No amount of lecturing will make the use of a new language instinctive. For adults to learn a new measurement language there must be considerable time and opportunity to use that language in real activities, without pressure. Once teachers are at ease with measurement in the metric system, their students will find it simple. For very young children, learning the metric system is only as difficult as learning measurement and estimation.

The same materials are appropriate for adults and children alike. If I were planning workshops to teach teachers the metric system, I would build the program around actual projects and activities that call for measurement or estimation in a natural way. Since I am convinced that it is important to put concrete materials in the students' hands, I would use some of the ESS and African Primary Science (APS)[3] units, as well as certain mathematics materials that are now available. These include—

Match and Measure; Peas and Particles; and *Mapping* (all ESS units).
Ourselves (APS).
Ways to Find How Many (University of Illinois Arithmetic Project).[4]
Cuisenaire Rods, centimeter-unit blocks, and others.

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[2] The Elementary Science Study is supported principally by the National Science Foundation.

[3] The African Primary Science Program is a project of Education Development Center supported principally by the U.S.A.I.D.

[4] The University of Illinois Arithmetic Project is a project of Education Development Center, supported principally by the National Science Foundation, the Carnegie Corporation of New York, and the Ford Foundation.

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In addition, I would—if time permitted—have *Pattern Blocks* and *Geo Blocks* (both ESS) and prototypes cut to centimeter scale. I would equip the workshop area with sandplay and waterplay tables full of an assortment of standard metric containers, and have a metric spring scale and an equal-arm balance with a balance beam perforated at centimeter intervals for balancing activities. In other words, I would have a simulated classroom or science-mathematics laboratory in which all of the ESS units could be carried on in a metric ambiance.

In working with teachers, I would simply introduce the units and materials, spending perhaps half a day on each unit, and requiring the teachers to use the metric system throughout. The primary focus of the activities would *not* be the mastery of the metric system through conscious process; it would be the introduction of new science and mathematics materials which the teachers could then take home to use with their pupils. It is like Zen and the art of archery: happiness, like hitting the target (and like the mastery of the metric system), is not what one tries for; it is the byproduct of repeated experience. After being steeped naturally in a new language, one finds one knows it—I know of no widely successful alternative.

d. "Match and Measure"—A Working Paper on a Unit of Elementary Science Study (see pp. 123–185)


MATCH AND MEASURE

MATCH AND MEASURE

A Working Paper

Published by the
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55 Chapel Street
Newton, Mass. 02160

PREFACE

The Elementary Science Study is one of many curriculum development programs in the fields of science, social studies, and mathematics under preparation at Education Development Center, Inc. EDC (a private nonprofit organization, incorporating the Institute for Educational Innovation and Educational Services Incorporated) began in 1958 to develop new ideas and methods for improving the content and process of education.

ESS has been supported primarily by grants from the National Science Foundation. Development of materials for teaching science from kindergarten through eighth grade started on a small scale in 1960. The work of the project has since involved more than a hundred educators in the conception and design of its units of study. Among the staff have been scientists, engineers, mathematicians, and teachers experienced in working with students of all ages from kindergarten through college.

Equipment, films, and printed materials are produced with the help of staff specialists, as well as of the film and photography studios, the design laboratory and the production shops of EDC. At every stage of development, ideas and materials are taken into actual classrooms, where children help shape the form and content of each unit before it is released to schools everywhere.

ACKNOWLEDGMENTS

We are indebted to the children who taught us that you can't *teach* measuring and who showed us many commonsense ways to learn how to measure. To them and their teachers we dedicate this book.

Norma Arnow contributed to the development of the activities by teaching and observing trial classes. Among other staff members, George Cope, Mary Gillmor, Jay Hauben, Emily Romney, and Virginia Strong added many helpful suggestions to improve the manuscript. Photographs were taken by George Cope, Joan Hamblin, Victor Stokes, and Allan Leitman. The book design is by Nancy Weston.

Elizabeth Barnett *Edith H. E. Churchill*

INTRODUCTION

Long

Tall

Big

Small

Children use these terms every day. Time and again, the words are heard in conversation and play.

"I'm going to make a *long* garage for my trucks."

"I can build a tower *taller* than myself."

"David is *small*, so he'll play my little brother."

Qualities, similarities, and differences are noted and expressed by children long before the questions--"How long. . .?" "How tall. . .?" "How much bigger. . .?" "How much smaller. . .?"--become meaningful or important.

Young children use size words to describe how they perceive things. Moreover, a child sees the size of one thing in relation to the size of something else. What he classifies as "big" in one instance, he may call "small" in another. A piece of cake served to him is "tiny" when all the other pieces are larger; it is "huge" when all the other pieces are smaller.

For a young child, the magnitude of objects is impermanent and changeable. His notion of the size of something depends upon how it looks to him at the moment. As a result, magnitude in terms of numbers has little or no value for the child. He may count out four dominoes in a pile and say that there are four, but when the same dominoes are spread out, he may think that there are more because they appear to take up more space. Similarly, when he sees the full box of dominoes he may say there are "a hundred," when actually there are many less. What he means is: "There are a lot."

Young children consider length, volume, and weight in much the same way. A row of blocks flat on the floor may look shorter than the same row standing up as a tower. Water poured from a drinking glass into a tall, thin tube may immediately become "more water" to a child, since the level of the liquid is higher in the tube than it was in the glass. He may think a ball of clay loses or gains weight when it is broken up into little pieces.

Under these circumstances, how can the young child approach formal measurement with understanding? The standard units of measurement used by adults make little sense to most children. What *is* an inch, a quart, a pound, if the quantity or size changes as the substance changes position or shape? What do the numbers attached to these inches, quarts, and pounds really stand for? How does "five feet" differ from "five inches" when both involve "five"? Even much older children are amazed and excited when they think of the difference between a million grains of salt and a million elephants.

The same experiences that enable a young child eventually to accept invariance of number, length, and quantity also help him to grasp the "why" and "how" of measuring. By handling solid objects, arranging and rearranging them, he finally becomes convinced that four dominoes stay "four," no matter how he places them. By transferring liquids from one container to another, he comes to see that a cup of water remains a cup regardless of the shape of the container it is in. By using the same, simple, direct methods for matching and comparing the magnitude of solids and liquids, he learns to measure. After a time, he is able to establish standard units of his own and to handle conventional measuring tools with understanding.

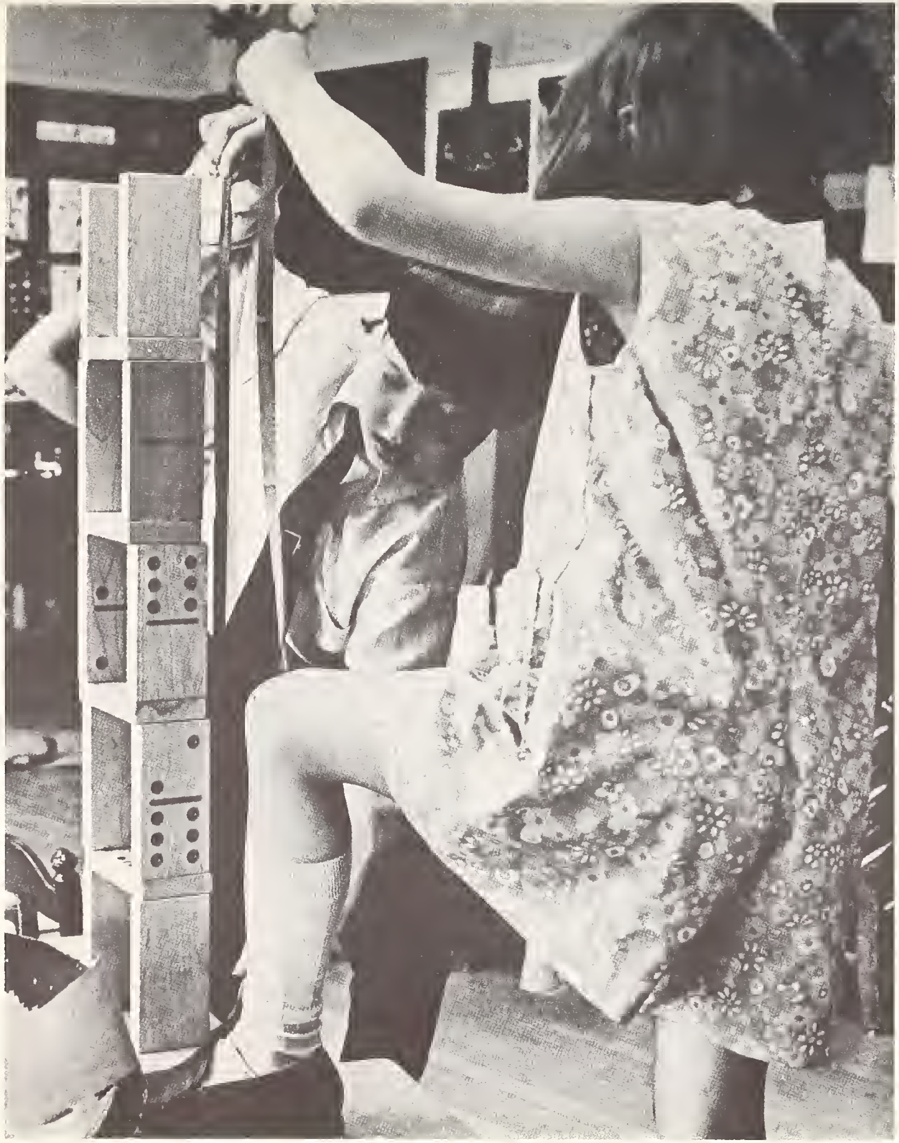
Conventional measuring devices lose much of their mystery and confusion if a child uses them alongside other tools of his own invention. When denied such experiences, children frequently assume that the use of conventional units of measurement is somehow essential to measurement itself. For some children, it seems as if length exists only when they have inches with which to measure it.

Perhaps the most urgent message this guide seeks to convey is that measuring should not --really *cannot*--be "taught," either through problems in arithmetic or through a series of planned lessons. Learning to measure is a gradual process; until a child has had a chance to establish in concrete, comparative terms what an inch and a foot are, "three feet plus two feet" is meaningless to him.

People measure to obtain information for some other purpose or to satisfy a curiosity. They seldom measure simply for the sake of measuring. Measuring in the classroom will be most effective and interesting if it is undertaken in the context of situations in which a child (or a group of children) is actively involved. Sewing, cooking, carpentry, and caring for animals are just a few examples of activities that capture children's interest while presenting measurement in a purposeful way. Children's activities abound in opportunities for measuring. To make use of these opportunities, children need encouragement to pursue questions that interest them, access to a variety of measuring tools, and the freedom and time to use these tools as they see fit.

The materials and activities presented in the guide are a response to the need expressed by primary teachers for suggestions of ways to incorporate measuring into the life of the classroom. The experiences and anecdotes cited illustrate different methods children have found to compare and describe lengths, surface areas, and volumes. The tools and materials are some which have served to make possible a variety of measuring experiences.

It is hoped that the teachers who use this guide will adapt, modify, and add to it in the light of their own classroom needs and circumstances over the period of the primary years.



Measuring is essentially a matching operation. The carpenter matches a board he wishes to cut against a ruler. The mother matches a roasting pan to the turkey, wrapping paper to a Christmas parcel, Margaret's last year's coat to her smaller sister. Periodically, Mark is matched against the wall where his height is recorded by a line drawn level with the top of his head. Even very young children become aware of this procedure and imitate it in their play.

The sorts of matching and comparing that children do and talk about as they build with blocks and play store, dress dolls and sift sand, are necessary preludes to understanding units of measure.

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SIMPLE MATCHING

The simplest matching and measuring operations require no tools at all.

Two children stand back to back to find out who is taller. One of them bridges the gap between their two heads with the palm of her hand in order to feel which head is higher.

Watching a few classmates compare their heights may give some children the idea of lining up the entire class, from the tallest person down to the shortest.

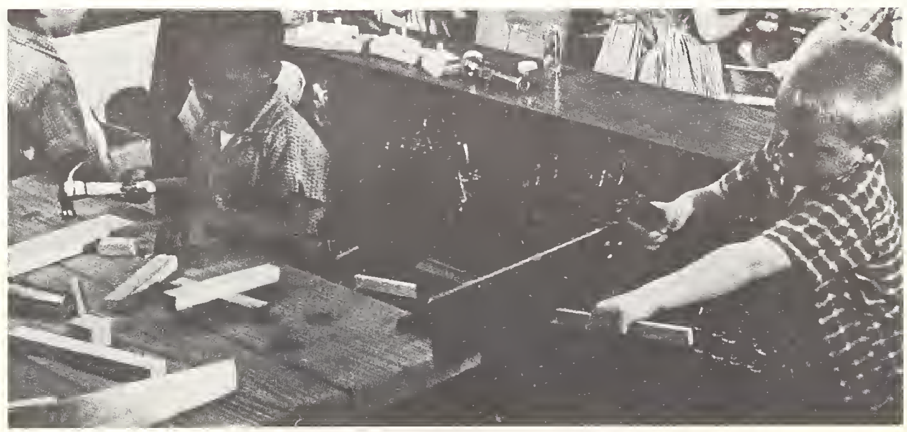
Just for fun--
Will the tallest person's shoe fit anybody else's foot?
Do you think that the shortest person's sweater will fit you?

The young owner of a new pair of shoes holds up one of his new shoes next to one of his old ones and announces excitedly, "My new shoe is a lot longer than my old one!"

Although the examples above are similar, the boy holding the shoes side by side may run into a problem not encountered by the children standing back to back. Does he think to line up the two heels so that both shoes are in the same "starting position"? Probably not, if he has had little experience making comparisons in this way. A child's ability to focus attention on both ends of the objects being compared develops as he matches many things--crayons, chalk, popsicles, lollipops--in many situations, over a period of time.

A wide variety of matching operations occur in children's play. The driver of a fleet of toy trucks suddenly decides to line up all his small trucks, his medium-sized trucks, and his large trucks in separate rows. He then proceeds to build a garage of blocks around each truck, ending up with small garages for his small trucks, and so on.

In the carpentry corner, the child struggling with a ruler soon learns that the quickest way of measuring a lid for a box is to trace the outline of the top of the box onto the board from which the lid is to be cut.



MEASURING LENGTH

String, Ribbon, and Ticker Tape

It is not always possible or convenient to match and compare actual objects against each other. Tools are often needed to do the job. String, ribbon, and ticker tape are good "tools" for early measuring activities. All of them can be stretched across or wrapped around things and can be cut or torn off at a desired length. These non-ruler materials enable children to measure without worrying about inches and feet. "Our classroom door is as wide as this piece of string." The piece of string becomes a "pattern" of the width of the door. When desired, "patterns" of width, length, or height of things can be kept as permanent records of measurements taken.

During the course of a school day, the need to measure can arise countless times for countless reasons. Once a child indicates that he is attempting to measure or compare the sizes of things, a helpful question or suggestion may open up new possibilities for him to think about and explore.

Building towers

Children often build tall towers of blocks just for the pleasure of watching them topple and crash.

Can you tell how tall your tower was before it toppled to the floor?

Who can build the tallest tower of all?

If a child chooses to construct his tower on a table, do the tower builders working on the floor agree when he claims his tower is the tallest?

Running cars down ramps

If there are toy cars around the room, sooner or later some boys will undoubtedly think of constructing different kinds of ramps for them to travel down. Here is an opportunity for the children to make comparisons involving not only distance but speed as well.

Does your car go as far coming off a long, low slope as it does off a short, high one?

Can you think of a way to keep a record of what happens with each car?

Which slope makes your car travel the fastest?

Playing house

Children often choose classmates by size to be members of a family for the housekeeping corner. Fathers usually turn out to be taller than mothers, mothers taller than children, older sisters taller than brothers. As children match their heights to determine who will play which role, a discussion may arise about the heights of actual family members at home. It might be fun for the children to measure their families and make a few comparisons.

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Can you bring in a record of how tall everyone is in your family?
Who is the tallest? . . . the shortest?
Where do you fit in?
Is the tallest person the oldest?

Try making the same sort of record of some of your classmates. If one of your friends is shorter than you, is his waist smaller than yours?
Is the person with the biggest waist bigger all over?
Compare arms, legs, heads.

Growing plants

Children who have planted seeds and are watching them grow may be interested in measuring their plants as they develop.

How tall is your plant today?
Do you think it will be the same height tomorrow? What about three days from now?
Can you keep a record and find out?
Some children have done this with strips of paper and made a graph.

Does corn grow faster than peas?
Is the taller plant bigger all over?

Shadow play

Shadows are intriguing. They can shrink; they can grow; they can disappear altogether. After playing such games as tag and follow-the-leader with shadows, children may become interested in looking more closely at their own shadows and at shadows of things around them.

How can you tell whether your shadow is as big as you are?
Some children thought of lying down on their shadows.
No matter how they tried, this never seemed to work.

Compare your sun shadow with yourself in the morning and again in the afternoon.
Did anything happen to your sun shadow?
Try doing the same thing with a stationary object in the room or outside of the building.

Can you make your shadow grow bigger? . . . smaller? Can you make it disappear?

For children who have become really interested in shadows and heights, here is something to try:
Darken the room. In one corner, place a lamp that gives off a pinpoint of light (a flashlight will work, too). Stand straight up and walk towards the lamp. Watch your shadow grow on the wall opposite the lamp. See where you have to stand to make your shadow go all the way to the top of the wall. Have several people take turns doing this. Who stood the closest? . . . the furthest?

Keeping animals

Animals in the classroom present possibilities for children to explore many kinds of measurement.

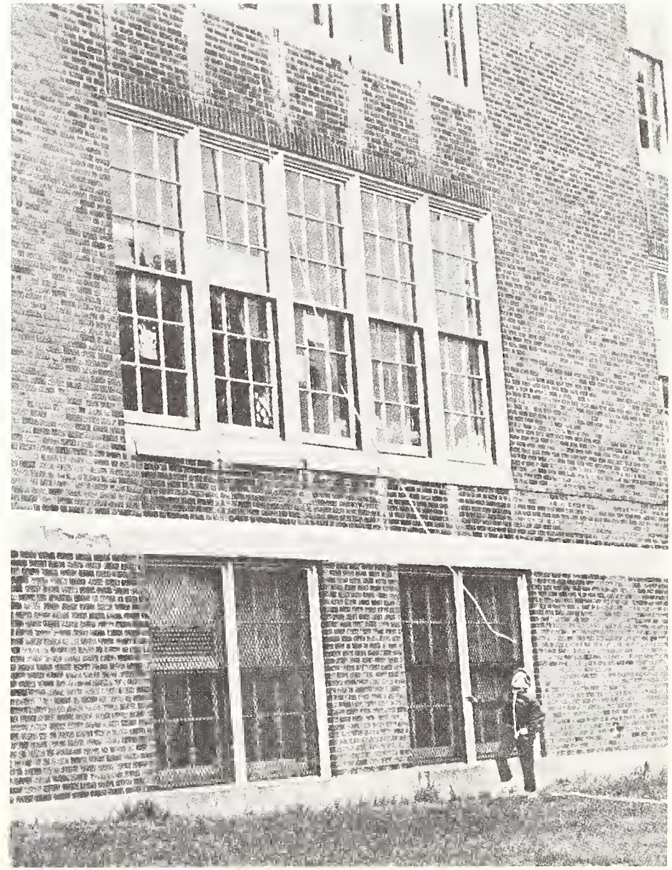
A group of youngsters had just about given up trying to measure their class guinea pig. A ruler was useless; the pig wiggled too much.
Aware of the children's frustration, the teacher made an effort to help them without telling them what to do. She simply stood near the group with a piece of string in her hand. It wasn't long before one child hit upon the idea of using the string to measure the guinea pig from nose to tail. After taking this measurement, someone asked for more string to find out how big the guinea pig was around the tummy. To everyone's amusement, the two measurements were nearly the same.

Children in a second grade were very impressed with the way a tiny gerbil could dig in the dirt. Taking careful measurements, they found that he was able to send the dirt flying behind him a distance greater than his own length (including tail) and that the mound of dirt he piled up was much taller than he was. The children speculated about whether they could accomplish such a feat, themselves.

Choosing a suitable cage for an animal may raise such questions as--
Is there room enough for the hamster to stand up?
. . .lie down? . . .stretch out? . . .run around?
. . .hide in a corner?

Measuring the "impossible"

After children have had some experience measuring ordinary things, they may look for something really difficult and challenging to tackle.



Two boys in a third grade wondered if they could measure the distance from their classroom to the ground. They decided to try using ticker tape. It worked pretty well.

Their next question was about the classroom itself. How far was it from the ceiling to the floor? Reaching the ceiling posed a problem at first, but they soon got around that by attaching tape to a long pole and standing on a table.

When the tape of the distance from floor to ceiling was stretched out on the floor, the children were surprised to see that it reached almost all the way across the classroom.

How would the window-to-ground measurement compare with that? As they unwound the first tape beside the second one, it became obvious that the distance from the window to the ground was much greater than the distance from the ceiling to the floor.

The teacher then asked the children if they could use the two measurements they had taken to figure out how many classrooms would fit between the measuring window and the ground.

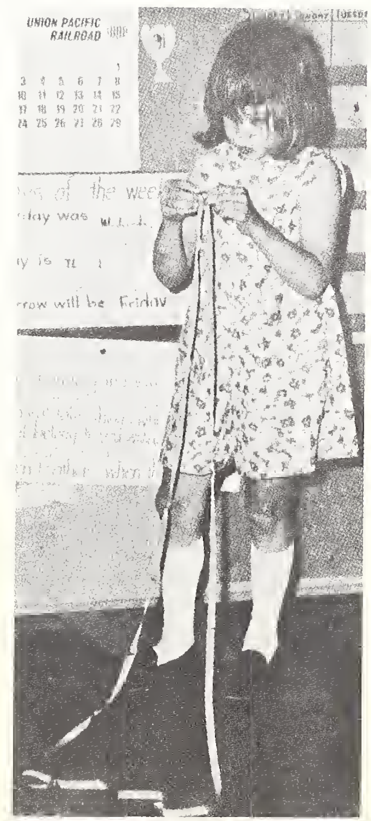
One boy made a guess that three rooms would fit. The other said four.

After comparing their two ticker-tape measurements, the children concluded that about two rooms would fit.

Measuring parts

Dealing with parts of a whole does not come easily to most children and should not be expected of them until they have had ample experience making gross comparisons. Once a child is able to grasp the meaning and implications of "larger," "smaller," and "the same," he can begin to think about whole things in terms of fractional parts and ratios.

An assortment of ribbons of different lengths in the dress-up corner helps introduce the notion of parts in simple ways.



Can you find a ribbon long enough to make a sash for your costume?

Suppose you wish to share a piece of ribbon with a friend. How can you divide it so that both of you will have an equal amount?
Try dividing the ribbon among four people. . . .among six.

The need for experiences like these is well illustrated by an episode which took place in a second grade classroom.

Two boys wanted to cut a piece of string in half. The string happened to be a little less than a yard long, though neither of the boys knew this.

Taking the string to a yardstick, one boy carefully measured off eighteen inches. His friend insisted that he knew a better way to do it and, grabbing the string, folded it in half.

The first boy was not convinced. To prove his point he matched the folded string against the yardstick and announced triumphantly, "You see, it's only seventeen inches, and it should be eighteen."

Hoping to help this child understand that there was an easier way of finding half than by using numbers, the teacher proceeded to cut a sizeable piece off the string. She then asked the boy if he could give his friend half of what was left. The boy was stumped.

Finally, the teacher put the problem to him in a slightly different way.

"Suppose you had a piece of bread, and you wanted to give me half of it. What would you do?"

"I'd fold it in two and rip it down the middle," the boy was quick to reply.

"Wouldn't that work with the string?"

The boy had to admit that it would, but he still insisted that "a ruler would be better."

Taking body measurements offers another way of looking at parts in terms of the whole. Children find it amusing to compare the distance around their heads with the distance around their waists, the length of their feet with their height, etc. Some of the relationships they discover surprise them.

Just for fun--
Try recording all your body measurements one after another on a single piece of string, the way some Chinese tailors do. Tie a knot in the string at the end of each measurement.
Children will probably need to try this several times before they catch on to the fact that they must take the smallest measurement first.

Working with random, fractional parts is a preliminary step to working with units such as inches, feet, and yards which are simply parts of a whole in one particular context. The more ways children learn to break down simple string-and-ribbon measurements into parts and into parts of parts, the better prepared they will be to understand the function of standard units of measure.

As the need to interpret and communicate measurements arises, the usefulness of these conventional standard "parts" will become clear.

Fingers, Hands, and Feet

Using ribbon and string is only one way of matching and measuring length. Another method which is time-honored, handy, and appealing to children calls for the use of parts of the body.

Long before a child enters school, he puts his body to work measuring in a number of ways. The act of reaching might well be the first of these. A baby reaches for a toy he sees, picks it up, gives it a toss, then reaches out to retrieve it.

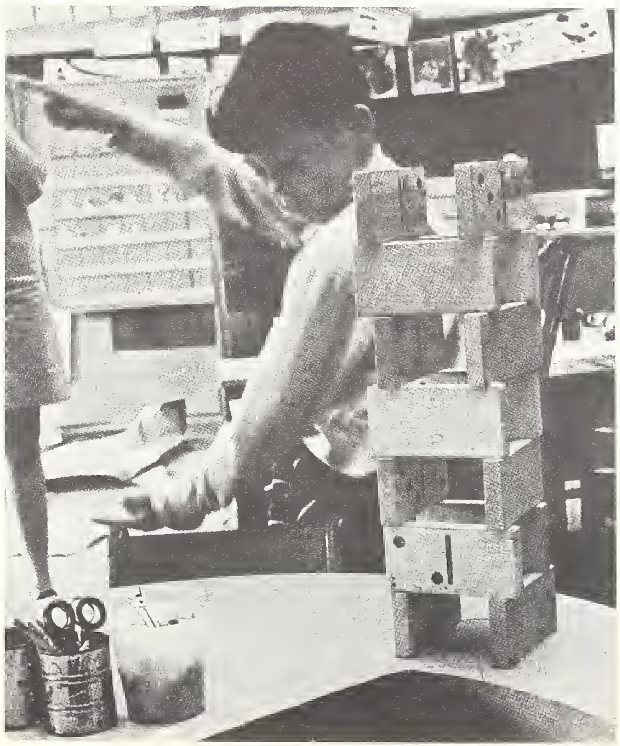
A few years later, it seems to the child that practically everything he wants or needs is out of reach: the shelf with the cookie jar, the hook for his pajamas, the light switch in his room. He tries standing on tiptoe, stretching his arms. He makes himself taller by climbing on a box or chair.

By the time the child is of school age, he is expressing measurement by making comparisons in terms of himself. Asked how big something is, he may spring to his toes and fling an arm into the air to describe the height of his father or a skyscraper, or he may cup his hands together and make himself small to convey the littleness of his baby sister or his pet mouse.

Eventually, the child develops new ways of taking and expressing measurements by observing how others go about this. He may see his father stake out a garden plot or badminton court in paces. He may watch in amazement, while his mother figures out the amount of material she needs for curtains by measuring fabric from her nose to her outstretched fingertips.

One way to start children thinking about parts of the body as possible measuring units is to play a matching game.

Can you find something in the room that is as wide as your hand? . . .as long as your thumb? . . .as tall as yourself?
Is your nose as long as your thumb?



Often a child may try the age-old method of measuring something between the index fingers of his two hands. The only drawback to this type of improvised ruler is that it tends to grow or shrink unpredictably. Measurements taken in this way prove unreliable. A child working on a piece of carpentry for the playhouse may discover that he has cut out an undersized door for an oversized doorway. Bungles of this sort teach children the value of taking measurements in a more dependable manner.

How many different ways can you use your body to measure?

One third grader attempted to measure the length of the school corridor with his head. He soon gave up this plan as impractical.

Two girls in another class went out into the schoolyard and measured the shadow of the flagpole in "splits." One found that it was four and a half splits long, the other found that it was five. Soon the girls were joined by two boys who suggested that they all measure the shadow with their feet. At first the children tried covering the shadow with footprints they had cut out of newspaper. When they discovered that there were not enough footprints to reach the end of the shadow, they decided to walk the length of it instead. Each child took a turn. One of the girls counted nineteen feet, the other counted twenty-three. Both of the boys counted seventeen.

"My feet are smallest. I used twenty-three," announced the girl with the "most foot counts."
One of the boys wanted to revise his count and make it less. "My sneakers are too tight so my feet are really bigger."
All the children agreed that the shadow of the flagpole looked shorter than the pole itself.
The children made plans to measure the shadow of the pole throughout the next day to see how it changed.
None of them was sure whether or not it would ever grow longer than the actual flagpole.

Children in other classes used hands, arms, and feet to figure out new arrangements for their desks and chairs, tables and bookcases.

How far apart can you move two desks and still touch both of them at the same time with part of your body?

"Stepping off" to measure a sizeable distance strikes most youngsters as more logical than using a ruler. ("The ruler isn't long enough," is a comment frequently heard.) A child soon discovers, however, as did the children measuring the flagpole, that few people take the same number of footsteps while walking the same distance. He may be quick to notice and point out that not everyone has the same size feet. Can he think of other reasons why foot counts vary?

Does it matter how you put your foot down when you are measuring with your feet?
Does everyone put his foot down the same way?

With experience, children come to understand the importance of using a measuring tool precisely--in this case, of placing one foot ahead of the other, heel to toe, over and over again along the path to be measured.

Although parts of the body are not very uniform instruments for measuring, they are useful for rough approximations, which children should be encouraged to make. A standard stride, for example, comes in handy when you are taking photographs and must stand a certain distance away from your subject. In time, children learn to judge when approximation is acceptable and when greater a accuracy is called for.

After children have done a good deal of matching and measuring in terms of body units, they might like to try estimating the length, width, or height of things by just looking at them.

Pick out something in the room. Try to estimate its size in hands, or in feet, or in people's height, etc.
Now check your estimate.
How close did you come?

Making estimates helps children think about the most suitable unit to use for measuring.
Which body unit would you choose to measure--
. . .the height of a giraffe?
. . .the width of a house?
. . .the length of a mouse from nose to tail?

Sticks, Tape Measures, Calipers, and Measuring Wheels

While some children may find ribbon and string satisfactory, others may prefer using hands and feet. Still others may seek out such devices as "sticks" (ranging anywhere from paper clips to yardsticks), tape measures, calipers, and measuring wheels. A variety of materials in the classroom offers several ways of looking at the measuring process.

Children often express measurement in terms of the things they are playing with. David makes a train of blocks "eight cars long." It takes "seventeen sticks" to fence in the barnyard Tom and Billy are building.

Can you tell how large your wrist is from the bracelet of paper clips you are wearing?

Youngsters in many classes found it interesting to make stick measurements of various distances within a school building--for instance, from their desks to the drinking fountain, from the sink to the aquarium tank, from their classroom to the cafeteria.

Which "stick" do you think would be most handy for measuring the length of the room? A soda straw? A popsicle stick? A yardstick?

In their first attempts to measure distance, children may want to construct an actual line of sticks from one point to another. When they run out of sticks before reaching their goal, someone may come up with the idea of reusing a few of the first sticks in the line or of using a single stick over and over again to finish the job. This new method should help children see the advantage of using only one size of stick and the need for paying attention to the end point of a stick each time they move it.

Children frequently find that a distance they are measuring does not come out to an even number of blocks or sticks or paper clips. How do they go about interpreting the measurement when the answer falls between two figures? Those who are unable to deal with fractions may be satisfied with counting the number of whole sticks that fit into the distance.

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For some measurements, rulers and yardsticks are not appropriate. These are times when tools such as calipers and measuring wheels will do the job more easily.

Calipers can open up and be made to fit hard-to-measure places.

Children in a second grade had a great deal of fun measuring their classmates with giant-sized wooden calipers. After measuring everybody's height, they tried using the calipers for measurements they had been unable to take with rulers or tape. To their delight, they found that they could measure the width of a person's head, his neck, his ankle, his toe, etc.

A measuring wheel can run up walls, follow-
a wiggly trail, or go around the block.

Can you tell how far the wheel goes in one turn?
Many first graders in trial classes walked the wheel to and fro aimlessly, counting as they went.
After racing wheels from the principal's office to their classroom door, one child announced that the distance was thirty-two turns, while another child declared that it was fifteen.
A third member of the class objected, stating that he, too, had measured the distance and found that it was only eight.
"I measured it with a yardstick, and the yardstick and the wheel are the same. I know they are, because I rolled the wheel on the stick, and the arrow on the wheel pointed down at the begininng and the end."

Once children catch onto counting the turns, they enjoy using the measuring wheel over long distances.
Walk the wheel home. How far do you live from school?

Can you use the wheel to--
. . .lay out a baseball diamond?
. . .find out how far seeds travel from a tree?
. . .find out how far you can throw a football or hit a baseball?

How does your bicycle wheel compare with the measuring wheel? Do both wheels go the same distance in one turn around?

Youngsters who are encouraged to think about how one measurement relates to another will be less likely to make hasty assumptions such as, "I know the measuring wheel isn't a foot, so it must be a yard."

When a child finds out for himself that three rulers add up to the same length as the classroom yardstick, he will have a useful working concept of the relationship between a foot and a yard. Terry may insist that the bookcase in the corner is three feet long; Robin, that it is a yard long. How do they resolve their dispute? Do they think of placing the yardstick and the ruler side by side?

The confusion many inexperienced children are likely to encounter before they have stumbled on some of the common relationships in measurement, is illustrated in the following interchange between a first grader and her teacher:

Maureen was trying to find out how tall she was with a roll of ticker tape.
Stepping on the end of the tape with one foot, she proceeded to unwind the roll until the tape reached the top of her forehead. She then asked the teacher to cut the tape in two where her fingers were holding it.

Maureen (catching the piece of tape as it fell, and matching it against herself) - "It's too long, Oh, but that's because I was standing on it."

After tearing off the amount of tape she figured she had been standing on, Maureen walked around the room with the remaining piece that matched her height. She held the tape first up to the door, then up to the chalkboard. Finally, she spied a yardstick.

Maureen (bringing the yardstick to the teacher) - "What's this?"

Teacher - "A yardstick."

Maureen (holding the stick up against herself) - "Look, I'm a yard tall!"

Maureen then placed the tape of her height carefully on the yardstick. It was obvious, at once, that the tape was longer than the stick.

Teacher (pointing to the portion of tape extending beyond the yardstick) - "But what about this?"

Maureen - "Oh, we can cut if off."

Teacher - "Do you think we could use the yardstick to find out how long this little piece is?"

Maureen (looking at the yardstick and the left-over piece of tape) - "Nope. The yardstick's too long."

This anecdote is typical of what can be expected of inexperienced young children in their early efforts to measure. As experiences are assimilated, children gradually develop more sophisticated concepts. The mature thinking of which third graders are capable is illustrated in the following story. These children had experimented widely with measurement, using a variety of methods and equipment. They had tackled measuring as a practical problem and had come to rely on their common sense.

The children thought that it would be fun to see if they could find out the height of their school flagpole by measuring the length of its shadow. As soon as the sun came out, some of them went about measuring the shadow of the pole with yardsticks while others measured the shadows of their buddies.

Mark's shadow turned out to be two feet, two inches long. "That's half as big as I am," declared Mark. "I'm four feet four." Someone then voiced the idea that if Mark was twice as tall as his shadow, the flagpole should be twice as tall as its shadow. The shadow of the pole measured nineteen feet. The children calculated from this that the pole must be thirty-eight feet high.

At this point, Sarah, who had brought along the large wooden calipers, decided to check the measurement another way. She opened the calipers until they matched Mark's shadow. Turning the calipers end over end along the shadow of the pole, she found that Mark's shadow fitted into it nine times.

The children had a feeling that they could use this information to determine the height of the pole, but they were not sure how to go about it.

To help them understand their calculations, the teacher stepped in at this point and drew a diagram of the flagpole and its shadow and of Mark and his shadow. After marking off the number of times Mark's shadow fitted into the shadow of the pole, the children concluded, "Then Mark himself will go into the flagpole nine times."

Thirty-nine feet was the figure established for the height of the pole.

Turning their attention to the results they had reached by two different methods, the children were interested in the fact that the answers arrived at were almost the same. A discussion developed about measurement and the accuracy of measurements.

"You could never measure exactly," insisted John. "Nothing is completely accurate, except two and one is three and things like that."

A short while later the boys went off to check with the principal on the height of the flagpole. They were pretty certain he would know how tall it was, "because," they explained, "you have to pay for flagpoles by the foot."

MEASURING AREA

Paper, Cloth, and Pieces of Wood

Through activities with cast-off materials and clothing in the doll corner and the playhouse, or with pieces of wood at the workbench, children become involved with two-dimensional measurement and learn how to deal with it.

Odds and ends of yard goods provide young children with countless opportunities to cover a surface: to make tablecloths for the playhouse table, a cover for the doll's bed, costumes for dressing up, etc.

Pattern-making takes children a step further and challenges them to experiment with different ways and means of measuring surface area. Patterns for puppets, costumes, doll dresses and accessories are a few of the possibilities that can be explored. Newspaper or large rolls of wrapping paper should be on hand for this purpose.

A class of first graders undertook to make paper patterns of themselves.
Large sheets of wrapping paper allowed the children to stretch out full length.

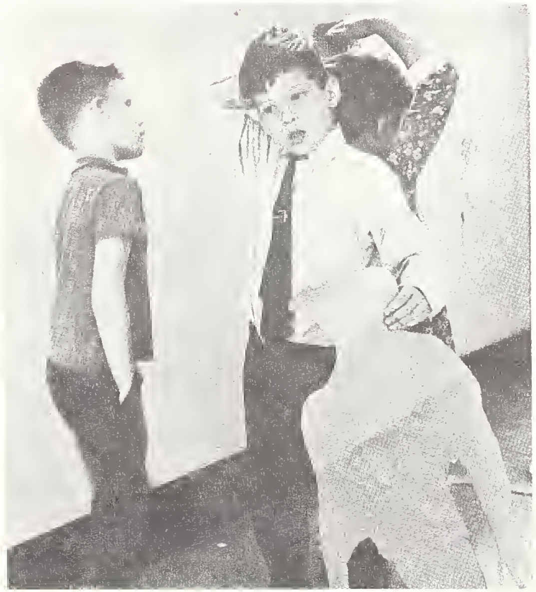
The patterns were cut out and matched against their models.

"It's taller because it's on tiptoe."

"Now we're both on flat feet."

After painting in faces and clothing on their patterns, the children decided to arrange them by height.

It wasn't always easy to tell who should follow whom.



Often live models had to be checked against each other.

Finally, the paper figures--"flat feet" and all--were lined up along the school hallway.

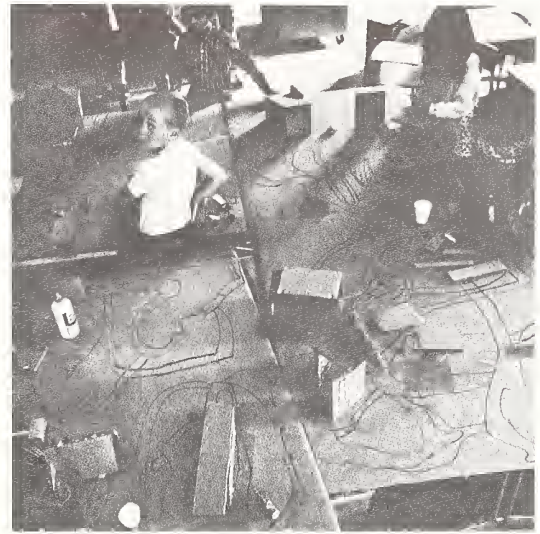
The line-up soon started some youngsters guessing about how many "paper children" it would take to reach the ceiling. One child said, seven; another, nine.

The teacher good-naturedly accepted the rather hazardous job of stacking the patterns feet on head up the wall.

Everyone was surprised when it took only three children to reach the ceiling.

In their early efforts at making clothes, children rarely think of allowing for seams or the thickness of the body. Rather than warn them of this, it is better to let them find out about it for themselves. After they have experienced the frustration of turning out costumes that don't fit, they will try other techniques for making patterns, such as wrapping paper around themselves or the models they are working with. Arranging a pattern on a piece of cloth is not easy. With practice, children develop an eye for conserving space and getting the most out of a piece of material.

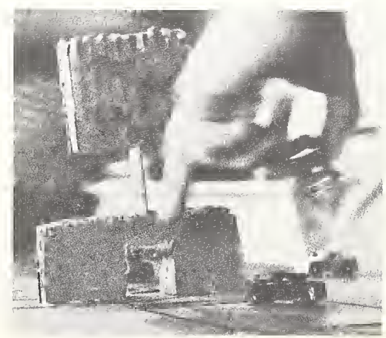
Models and maps, decorations and scenery, creations of papier-mâché offer still more opportunities for children to work with two-dimensional space.



Models and maps

Model houses, towers, and the like, made from assorted boxes and cans, will be more attractive if they are covered with newspaper before they are painted. As they decorate, children will need to figure out ways to cover a variety of shapes, not only rectangles and squares, but cylinders, cones, and spheres as well.

Making relief maps gives children experience with irregular shapes, such as mountains, gullies, and roads.



Some third grade children decided to make a large map of their city. Separate groups of children worked on four different parts of it. When the sections were finally put together, the children found, to their surprise, that many of the streets did not meet as they should, and that the scale of the buildings varied tremendously from section to section.
One child, who had constructed an underpass for vehicles, found that buses and trucks got stick in the tunnel she had made. She solved this problem by putting up a sign, "For cars only."

Decorations and scenery

Planning a wall mural or designing scenery for a class play calls upon children's ingenuity and ability to work with large areas. The kind of measuring they do for a mural will depend upon whether wide rolls of paper are available or whether small pieces of construction paper are to be used.

What shall we use as a backdrop for our play?
Is an old bed sheet large enough?
What can we fit into the scene we paint on it?
Is there room enough for two houses or just one?

How many sheets of newspaper would you need to paper the floors or the walls of the entire school?
How many Sunday papers would you need to cover the whole city?

Creations of papier-mâché

A number of children in trial classes made puppets out of felt and papier-mâché. One boy thought of using a blown-up balloon as a mold for the head of his robot. Several of his classmates became interested in the problem of how to cover the balloon with paper. It took several tries before they discovered that strips instead of whole sheets of paper worked best.

Geoboards, Pattern Blocks, Bricks, and Tiles

Geo board, Pattern Blocks (similar to small parquetry blocks), and comparable materials invite a child to create and manipulate two-dimensional space.

Children like to fiddle with rubber bands on a Geo board, making mazes and shapes of all sorts.

In one second grade, children's attempts to construct mazes resulted in a game. One player would devise an intricate network of paths on the board and then challenge another player to follow it to "Grandma's house." Players vied with each other to see who could create the longest and most complicated walk.

Try making a long low house, a tall skinny house on the board. . . .a barn. . . .a skyscraper.
Can you tell which one takes up more of the board?
Which house would you build in the city? Which, in the country?
Why are city houses the shape that they are?

Can you make a house or apartment like the one you live in?

Pattern Blocks appeal to the eye and to the touch. Some youngsters like to build with them; others are more interested in making designs out of the various shapes. By arranging and rearranging the blocks into different patterns, children gradually become aware that several combinations of different block shapes can fill the same space. For instance, an area as large as four trapezoids is also as large as six blue diamonds or twelve triangles.

Tiles and bricks on the wall or in the floor are particularly useful for approximating length and area.

One third grader wished to compare his actual height with the height of his shadow. Measurements of both were taken in string. Lacking a yardstick, the youngster quickly resorted to making the comparison against bricks in the wall of the school building.

Some children in trial classes enjoyed tossing loops of cord or soda straws threaded end to end on a string onto a tile floor to see who could make the biggest "pond." If children care to make a really long chain of soda straws, around fifty feet or so, they can also try fencing off large blocks of space.

MEASURING VOLUME

Cups, Containers, and Tubes

Sand or water play with cups, containers, and tubes is a pleasurable introduction to the concept of volume. Indeed, all the pouring, filling, and spilling that accompany such play are vital experiences no child can afford to miss.

Activities with sand and water are best handled in small, informal groups. (When sand is not available, dry materials such as sawdust, cornmeal, peas, or rice--almost anything that can be poured--may be substituted.) An area for sand or water play can be set up in a classroom with the following materials:

A large container:	a plastic wading pool, an infant's bathtub, or a galvanized washtub
Floor covering:	newspapers for sand or water, or a large sheet for sand.
A wide assortment of smaller containers in regular and odd shapes:	school milk cartons; quart, half-gallon, and gallon milk cartons or bottles (whichever the children are accustomed to seeing); juice cans; plastic refrigerator containers; cups (assorted sizes and shapes of paper cups; standard measuring cups; coffee, tea, and medicine cups); squeeze bottles in different shapes (some of the same capacity); turkey basters; plastic tubing; funnels; a set of measuring spoons.

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Before tackling the business of measuring volume, children should be allowed plenty of freedom and time to "mess about" with the materials on their own. Preliminary play may last days or weeks, depending on the age and experience of the children.

Building sand castles, constructing waterways, pouring sand and water over hands and through funnels, teach the inexperienced participant as much about spatial relations and magnitude as about the nature and behavior of the materials he is handling. Many of the explorations children pursue with the materials involve no measuring at all.

Through sand play and water play, children deal with three-dimensional space and begin to establish basic notions about it. They may not wonder about precisely how much water and how many cups of sand they have for some time. Until they do, youngsters should not be forced to measure for the sake of measuring--a pointless pastime which can restrict thought and action to sterile exercises in counting.

Measuring should take place when and if interest in it arises. Castle builders may wish to find out how much water will fill a moat; water-system operators may need to compare the capacity of different-sized tubes. First encounters with measurement often occur quite by chance.

A second grader was pouring water from a plastic tube into whatever cups and containers she found handy. Suddenly she made the discovery that her milk carton from lunch held the same amount of water as the tube. This amused her. Laughing, she told the teacher, "I drink a whole tube of milk twice a day!"

Children are certain to be surprised at the capacity of some of the cups, containers, and tubes when they compare them. A short, fat jar may turn out to hold the same amount of water or sand as a tall, thin tube.

Children who have done only linear measuring and who have had little experience with pouring and filling are likely to reach for rulers and try using them to make comparisons of volume.

One second grader selected a short, wide container and a short, slender vase. He filled both with water and then measured the height of each with his foot rule. When the two containers turned out to be about the same height, the boy was confident that both held the same amount of water.

Another classmate objected strongly to this method of measuring. Pointing to the top of one of the containers, she commented that the boy had forgotten "all the part in here."

The boy then attempted to measure the diameters of the containers. His classmate still wasn't satisfied. "What about the part below? . . .all of this? The girl picked up an empty jar and thrust her fist into it, to show that she meant the entire inside, not just the top surface.

At this point the boy shrugged his shoulders and gave up. The girl struggled with the problem a while longer until she hit upon the idea of pouring water from one container to the other to see if they both held the same amount.

Most children are able to accept and use the strategy of pouring the contents of one container into another in order to compare the volumes of both, only after a great deal of pouring and filling experience. The fact that the quantity of the contents remains the same even though the shape of the containers into which it is poured changes, is difficult for youngsters to believe. The full contents of one container poured into another sometimes appears to become larger, sometimes smaller. Children often think that when the amount "looks large" that means the container is larger.

Sometimes the water or sand that fills one container does not fill another. Does that mean the amount has diminished? Is the first container bigger because it is full, or is the second one bigger because more could be added to it? What if the water or sand overflows? Which container is larger then?

Children must work through these puzzling questions in their own way and in their own time before they can be expected to make comparisons and measurements with any degree of understanding. If there is balancing equipment in the classroom, some pupils may think of using it to answer their questions. In addition to sand and water, they might try balancing materials such as Play-Doh or Plasticine. A child who has balanced a lump of Plasticine as a ball and again as a snake may be surprised at first that the weight has not changed. He may even try cutting the Plasticine up in little pieces. Weighing activities should help reinforce the idea that a given amount of a material remains the same amount no matter what shape it is in.

Another good way for children to acquire a feeling for the comparative volumes of different shapes and sizes is through play with blocks. Standard kindergarten blocks and Geo Blocks are designed to stimulate such investigations. Fitting different-sized blocks together to make increasingly intricate structures gives children first-hand experience with area and volume relationships. Children who have done a lot of building with Geo Blocks will know, automatically, how many one-inch cubes it takes to construct a two-inch cube.

Everyday problems of how much and how many

Once children are comfortable with making comparisons of volumes, they can turn their thoughts to problems of how much and how many.

Daily meals offer a wide variety of opportunities for measuring. Mother coaxes Sally to take "just one more bite of liver ...one more mouthful of spinach ...one more tiny spoonful of turnips." To the balky eater, most of these measurements seem larger than they sound. Exactly how much *is* "one more"?

The total amount of food taken in each day by different living creatures is fascinating to consider.

How much food do your classroom animals or household pets eat every day?
Does the guinea pig eat a spoonful of pellets? . . .a handful? . . .a bagful?
What about--

. . .a gerbil?
. . .a bird?
. . .a fish?
. . .yourself?
. . .everybody in the school?

What about the plants in your classroom? Do they all need the same amount of water every day?

Having children make comparisons of the amounts of food consumed by themselves and their various pets is one way of working into standard units.

Can you compare how much you eat with how much your dog eats?
What did you use to make the comparisons? . . .cups? . . .spoons? . . .bowls? . . .numbers of meals eaten? . . .weight of each meal?

Just for fun--
A hummingbird sometimes consumes twice its weight in food in a day.
A shrew eats as much as one hundred times its own weight in food in one day.
If you ate one hundred times your weight, how much food would you consume in a day?
How many times your present weight will you eat in twenty years?

Formulas and recipes

Formulas given in parts also emphasize the need for establishing some arbitrary standard unit and for selecting a unit of an appropriate size for the purpose intended. (If you want to end up with a pailful, you will not want to measure it out in tablespoons.) Almost any kind of container can serve as a standard, provided it is filled to the same level each time it is used. Play-Doh, baker's dough, finger paint, and papier-mâché are a few examples of concoctions children can measure in this way. Older students might like to try following this formula for a chemical garden:

3 parts water
3 parts salt
1 part ammonia
3 parts bluing

Mix together and pour over rocks, sand, sponges, wood, or bits of brick and cement spaced out on a metal tray. Let stand. Watch the crystals grow!

The preparation of fruit punch for the entire class calls for a lot of practical measuring. Children must consider not only the proportions of the ingredients but the number of children to be served and the size of the drinking cups as well. Determining the yield of the pitcher or the bottle in which the punch is made may turn out to be a harder job than it looks.

When asked how many children using the same-sized cup could be served from a gallon jug, a youngster in third grade held the cup up against the bottle and proceeded to mark off how many times the cup fitted into the height of the bottle.
"Three," was her answer.
"Only three children from the whole bottle?" asked the teacher.
"Yes," replied the girl, holding the cup up to the bottle again, "Three children."
After the child had poured out two cupfuls, making scarcely a dent in the contents of the bottle, the teacher asked the girl what she thought now.
The child clung to "Three."
It was not until the third cupful had been emptied out that she looked at the bottle which was still almost full, and said, "I guess it's more than three."

How much punch will you need to make to provide for refills at your party?
What if there's some punch left over? Can you pick out a container that is just about the right size to hold what's left?
Try finding a container of the right size for all sorts of leftovers: clay, crayons, marbles, etc.

Cups, pints, quarts, and gallons become real to the child as he handles them. Distinguishing one quantity from another becomes important to him when there is reason for telling them apart.

Children in a second grade set about the task of changing the water in their fish tank. The teacher reminded them that tap water must be treated with conditioner before it is added to a tank. The directions on the back of the bottle of conditioning tablets called for one tablet for each gallon of water.

Although most of the children knew the word "gallon," none of them had any idea of the amount it stood for or of how to go about getting it. After rummaging through a variety of containers around the room, someone came up with a milk carton marked "one half-gallon." Putting their heads together, the children came to the conclusion that two half-gallons would make one whole gallon. From there they went on to find out how many gallons it took to fill the bucket in which they mixed the conditioner, and how many buckets it took to fill the fish tank.

How many different ways can you find to make a gallon?

Most cooking recipes call for conventional standard measures. Simple recipes for puddings and cookies are fun and easy for youngsters to follow.

In one trial class, a group of students became interested in making bread. To produce a loaf of bread good enough to eat requires careful measurement of volume, temperature, and time. The making and baking of loaves that were eatable and loaves that were not taught the young bakers a lasting lesson about the usefulness of measurement.

MORE MEASURING

The kinds of measurement focused on in this book are those which can be approached physically, either by making direct comparisons between things or by using a tool to determine size.

Time, temperature, weight, rate, value-by-price, and size-by-number (such as the population of a city) are equally interesting for children to explore. Activities relating to these forms of measurement can evolve out of classroom situations in ways similar to the ones described in this book. Whatever avenues children choose to investigate in the realm of measuring will contribute to their understanding of all measurement.

SOME USEFUL MEASURING MATERIALS

measuring sticks

- unmarked, wooden slats of varying lengths, including at least one three-foot length and a meter length (Try painting a few slats with chalkboard paint, so that children can mark units on the sticks when they feel the need for them.)
- twelve-inch rulers
- standard meter and yardstick combination on separate yardstick and meter sticks
- tongue depressors
- popsicle sticks
- soda straws

ball of string

ticker tape or party streamers

box of discarded Christmas ribbons of assorted lengths; seam binding

tape measure

measuring (trundle) wheels - 36" circumference (available from Webster Division, McGraw-Hill Book Co., Manchester, Missouri 63011)

large calipers - 36" long (can be made by attaching two wooden slats together with a bolt and a wing nut)

FOR THE PRIMARY CLASSROOM

standard plastic measuring cups--one- and two-cup capacity

coffee scoops

measuring spoons

assorted plastic and paper cups, including some small medicine cups

milk cartons or bottles--quart, half-gallon, and gallon

plastic refrigerator containers--a variety of sizes

plastic paint pails

clear plastic tubes (available from wholesale distributors of plastic bottles and containers)

funnels

Geo boards (available in plastic from SEE, 3 Bridge St., Newton, Massachusetts 02158)

A Geo board can also be made fairly easily out of a 12-inch piece of plywood and 100 small nails (1/2" brass escutcheon pins are best). The nails should be driven partway into the board, an inch apart along horizontal and vertical lines, giving you a 10 x 10 grid.

Pattern Blocks (available from Webster Division)

Geo Blocks (available from Webster Division)

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ESS UNITS THAT CONTAIN ACTIVITIES INVOLVING MEASUREMENT

Peas and Particles
Structures
Light and Shadows
Growing Seeds
Sand
Primary Balancing
Geo Blocks
Pattern Blocks

How Much and How Many: The Story of Weights and Measures, by Jeanne Bendick (New York, McGraw-Hill, 1947), describes the origins of weights and measures--what they are, how they got that way and why. Written in a light, informal style and illustrated throughout with humorous black-and-white drawings, the book makes delightful reading for children as well as adults. The folklore makes this book worthwhile, even though the scientific information is often inaccurate.

Counting and Measuring: An Approach to Number Education in the Infant School, by Eileen M. Churchill (Toronto, University of Toronto Press, 1961), deals primarily with the teaching of numbers in the primary grades. Along with her treatment of the beginnings of mathematical understanding in childhood, Eileen Churchill presents stimulating ideas about how children explore measurement and space, and about the role of the teacher in the primary classroom.

Some Aspects of Piaget's Work (National Froebel Foundation, 2 Manchester Square, London W. 1, 9th ed., 1966), contains excellent summaries of some of the work of the Swiss psychologist, Jean Piaget: "Children's Ideas of Number," "The Wider Significance of Piaget's Work," "Piaget and Progressive Education." All have to do with the thinking and reasoning of the young child.

Mathematics In Primary Schools: Curriculum Bulletin No. 1, The Schools Council, by E. E. Biggs (London, Her Majesty's Stationery Office, 2nd ed., 1966), gives many useful examples, through classroom anecdotes, of the ways some teachers have handled the development of mathematical concepts in English infant schools.

Nuffield Mathematics Project Publications (New York, John Wiley & Sons, Inc., 1967); two of the most useful booklets from the series are mentioned here:

> *I Do and I Understand* describes how a number of British teachers have changed their classrooms in order to provide a setting that will give children a better opportunity to learn. To quote from the introduction, "To achieve understanding, young children cannot go straight to abstractions. . . .they need to handle things. . . . But 'setting children free' does not mean starting a riot with a roomful of junk for ammunition."
>
> *Beginnings I* deals more specifically with examples of how equipment is used to generate learning. Children's work illustrates the book.

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Appendix VII

Equipment Lists for Occupational Education Programs

Through the courtesy of Professor Charles F. Ward of the Division of Occupational Education of North Carolina State University, we secured the equipment lists compiled for over a hundred different occupational curricula by the Division of Occupational Education of the North Carolina Department of Community Colleges. These curricula were arranged in alphabetical order and numbered by the North Carolina Division of Occupational Education: The absence of many numbers from the sequence suggests that the list is quite incomplete.

The North Carolina list overlaps to some extent the list of occupational curricula offered in the public colleges of the California Community Colleges. The overlap indicates common and nationwide needs—the lack of complete correspondence is due in part to the inferred incompleteness of the North Carolina lists and to local needs and interests—e.g., there would not likely be a course in oenology in North Carolina, nor a course in textiles technology in California.

Each list obtained from North Carolina is a detailed and priced inventory of the equipment needed to open a curriculum for a specified number of students, ranging from 12 students to 30. The lists were examined by the project director. He identified the items that would have to be replaced, supplemented, or modified in order to teach a suitably metric curriculum; these costs were totaled for each curriculum.

The estimated costs of replacing small and large items (*R/small* and *R/large* in the table) at a break-point of $50 and of small and large modifications (*M/small* and *M/large* in the table) at a break-point of $100 were summed, and the results are tabulated on the following pages.[1] The lists which showed significant costs were sorted into groups of related subjects and each group was examined by an occupational education specialist in that area to see if the list seemed to be reasonable for the curriculum, and to check on the earlier estimate of the cost of metric conversion.

Our observations at project FEAST showed that very little would need to be changed in the kitchens and bakeries of this sector of occupational education. Thermometers would have to be replaced, but they are an inexpensive component of the ovens they monitor. Scales and volume-measuring containers are much more important in baking than in cooking, yet even there

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[1] The sums are rounded to the nearest hundred dollars. The modifications are typically the replacement of gauges, thermometers and linear scales as small components of larger systems, and the replacement of lead screws and other major components of relatively expensive machinery. The latter were estimated at 10 percent of the cost of a new machine for small machines and 5 percent for larger machines. These modifications have been outlined in "Measure for Measure: a Guide to Metrication for Workshop Crafts and Technical Studies," see the Bibliography, p. 200. A lathe can be modified for cutting metric screws by providing a different set of gears connecting the headstock spindle with the changegear box, while various dials can be obtained to read in both English and metric units simultaneously for use with crossfeed screws and with the feed screws of milling machines and other machine tools. A number of design possibilities are discussed in "Machine Tools for Metric Production," also described in the Bibliography, p. 201.

great precision is not required, and inexpensive modifications of existing scales can be made rather than the expensive modification which would seem to be needed in scales constructed to meet the standards of retail trade.[2]

We are indebted to Mrs. Hilda Gifford of Project FEAST, and to the following persons who helped us with the evaluation of the North Carolina lists: Tapan Banerjee, John Majkut, Richard D'Onofrio, and Edward Van-Dusen.

[2] Estimated at $150 per scale for manual computing scales in food retailing, and $1000 per scale for prepackaging printing scales, Conference report, Conference on Consumer-Oriented Industry, National Metric Study Conferences, Washington, D.C., 21-25 September 1970.

Table 1. Equipment inventories for selected occupational curricula—original costs and estimated costs for metric conversion

			Conversion cost breakdown				
	Number of students/or stations	Total cost of equipment	Total cost of conversion	R/large	R/small	M/large	M/small
Agriculture:							
Animal science lab	24	4,400	0		40		
Farriering lab	12	4,000	0		20		
Forest management lab.	24	35,000	2,500	2,400	80		
Horticultural science lab.	24	56,000	300	60	224		
Poultry science lab	24	5,300	0				
Wildlife science	20	22,000	200	120	50		
Health:							
Dental dark room	16	4,500	0				
Dental hygiene clinic	16	122,000	0				
Dental lab	72	179,000	1,800	1,785			
Dental operatory	16	42,500	0				
Dental materials lab	16	41,000	500	500			
Dental X-ray operatory.	16	22,000	0				
Inhalation therapy	15	71,000	[a]				
Medical office examining room.	20	23,500	100		110		
Medical records lab	20	15,500	0				
Operating room assistant.	12	3,500	0				
Physical therapy assistant.	20	31,500	100	90			
Sterilization area	16	5,700	0				
Office and Business:							
Accounting lab	30	6,200	0				
Interviewing and testing.	20	4,000	0				
Office machines lab	30	23,000	0				
Secretarial lab	30	22,000	0				
Stenographer lab	20	5,700	0				
Typing lab	30	7,300	0				

Table 1. Equipment inventories for selected occupational curricula—original costs and estimated costs for metric conversion—Continued

	Number of students/or stations	Total cost of equipment	Conversion cost breakdown					
			Total cost of conversion	R/large	R/small	M/large	M/small
Technical:							
Air frame/power plant mechanic.	40	275,000	1,300	820	360		125
Aviation management/ pilot technician.		16,000	750	225	20	500	
Civil testing	20	25,000	2,700	1,580	280	480	410
Materials testing	15	60,000	2,000	350	60	1,500	
Instrumentation	20	81,000	3,900	600	15	2,400	870
Photogrammetry	12	17,000	0				
Plant layout	30	673	0				
Production planning	30	700	0				
Quality control	30	6,100	0				
Surveying-advanced	18	62,300	400	380	30		
Surveying-related	18	13,500	1,100	990	85		
Trade and industry:							
Air conditioning and refrigeration.	20	17,000	1,000	725	280		
Automotive body	12	12,000	400	375			25
Automotive mechanics	16	70,000	4,400	1,035	600	2,655	135
Carpentry and cabinet making.	20	21,000	1,250	455	375	260	145
Diesel	16	79,500	1,700	705	221	785	30
Electrical	15	120,500	200		80		75
Electrical installation	20	30,000	[b]400	190	110		80
Electrical lineman	15	4,500	0		35		
Electronics	20	143,000	100		90		
Energized electric line	15	16,000	[c]500				
Electromechanical	20	40,500	1,000	750		200	
Food service lab	20	44,000	400				
Heating systems	20	14,500	[b]1,100		20	100	
Heavy equipment/ earth moving machinist.	15	102,000	[d]3,200	1,435	270	450	50
Heavy equipment/ earth moving operator.	15	880,000	0				
Hydraulic flow	16	16,000	1,100			900	200
Hydraulics and pneumatics	12	6,800	800			650	120
Industrial maintenance	20	93,500	[b]4,300	999	50	3,190	100
Instrument mechanic	15	22,000	1,500		15	760	715
Light construction	16	13,000	700	110	290	230	50
Machine shop	15	250,000	18,300	4,500	600	13,000	200
Machine tool	15	[e]64,000	8,300	2,500	800	5,000	
Masonry	20	4,000	200	120	40		
Model and pattern	12	3,500	0				

Table 1. Equipment inventories for selected occupational curricula—original costs and estimated costs for metric conversion—Continued

	Number of students/or stations	Total cost of equipment	Conversion cost breakdown: Total cost of conversion	R/large	R/small	M/large	M/small
Plumbing and pipe fitting.	20	4,200	[b]				
Radio and television ...	20	18,100	[e]100				
Sewing machine mechanics.	15	34,000	0				
Small engine repair	15	4,100	500	365	110		25
Telephony	12	30,000	0				
Textile manufacturing ..	20	95,500	[a]				
Time and motion study.	30	4,900	0				
Tool and die shop	15	230,000	20,000	1,500	500	18,000	
Transportation maintenance.	15	72,000	4,600	430	170	4,000	50
Upholstery cutting and sewing.	16	13,600	0		20		
Watchmaking	30	20,500	0				
Welding	16	178,500	3,300	1,485	65	1,725	65
Vending machines	20	23,000	90		90		
Fishery and marine:							
Fishery science	20	24,000	900	610	10	150	140
Marine technology	18	189,000	4,400	2,400	340	1,640	200
Marine mechanics	16	32,000	2,000	1,400	100	400	100
Applied art and graphic art:							
Art design lab	20	9,000	0		8		32
Commercial art and ad design.	20	37,000	100				123
Drafting and design	20	37,000	300	300	33		
Furniture design lab	20	21,000	0		50		
Graphic arts-general	20	33,000	[f] 300				
Graphic arts lab	15	326,500	[f] 1,000	150		750	80
Interior design lab	20	12,000	0		40		
Photo studio		30,000	[f]				
Public and personal services:							
Cosmetology lab	20	14,000	0				
Journalism	15	2,700	0				
Library technical assistant lab.	20	5,000	0				
Radio and television broadcasting.		232,000	0				
Recreational therapy ...	20	4,800	0				
Recreationl grounds management lab.	24	6,900	0				
Basic sciences:							
Chemistry-analytical ...	12	22,000	0				
Chemistry-industrial ...	12	6,000	0				

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Table 1. Equipment inventories for selected occupational curricula—original costs and estimated costs for metric conversion—Continued

	Number of students/or stations	Total cost of equipment	Conversion cost breakdown				
			Total cost of conversion	R/large	R/small	M/large	M/small
Chemistry lab-general . .	12	26,000	0				
Chemistry-organic	12	10,500	200	200			
Chemistry-physical	12	1,500	0				
Environment chemistry and biology.	16	64,200	0				
Life science lab	24	8,500	0				
Marine biology	20	75,000	0				
Physics-technical	24	24,000	0				
Physics-vocational	24	12,500	100				

[a] Depends on industry.
[b] Depends on pipe thread changes.
[c] Estimate.
[d] Modification of government excess machine tools, estimated at $1000, may exceed inventory value.
[e] Small tools.
[f] Depends on changes in the printing industry.
[g] This inventory listed many used or surplus machine tools.

Some Prospects for Technical Occupational Education and Engineering Education

It is easier to say what occupational education is not than to try to write a definition which would be acceptable to most of the people working as occupational educators. On the one hand, occupational education is more than merely learning job skills; but on the other hand it does not include the training of scientists, engineers, medical professionals and academic teachers, although they are most certainly being educated for their future occupations.

The accompanying diagram of a "career ladder" in certain technical areas can be roughly divided into thirds, with rather fuzzy boundaries between them. On such a diagram, occupational education concerns itself with the middle third. The boundary "engineer—technologist—technician" is in a state of flux, and some people expect changes to occur in this region during the next two decades which will be of such a magnitude as to dwarf the technical problems of engineering education which may arise from metric conversion. During this period, the faculties of colleges of engineering will adapt to the distinction between engineering and engineering technology. It is frequently remarked that many young men are trained as engineers and then find employment as engineering technologists in effect; that is, they work as highly qualified assistants to the engineers who are the source of originality in solving engineering problems, and who have the management skills and judgment needed to carry complex projects to successful completion. In this role they become specialized in ever narrower fields and lose the flexibility and breadth of view which is essential to being an engineer.

The implementation of this distinction is beginning to occur in the structure of engineering education. Curricula leading to the associate degree in engineering technology are well established in junior colleges, community colleges, and technical institutes both public and proprietary; and bachelor-degree programs in engineering technology are being started in independent colleges and proprietary schools. Plainly, changes will also occur in the established schools of engineering. (Similar changes may be expected to occur in the structure of career ladders in the medical occupations and in the occupations based in behavioral science which are expected to become important occupations in the near future.)

In recognition of this imminent reorganization of the engineering profession, and as a measure of its magnitude, the Engineers Council for Professional Development have predicted that the ratio of engineers to technicians-and-technologists may be expected to change from the present ratio of about three to two to a ratio of about one engineer to each 8 to 12 technicians and technologists.

Professional, Technical, Craft, and Industrial Occupations

Education-Training	Titles	Divisions	Employment
University 4, 5, 6, or more years. BS, MS, Ph.D.	**SCIENTIST**	Physicist Chemist Mathematician Metallurgist	Research Invention Design Development Teaching
University 4, 5, or 6 years. BS MS, Ph.D.	**ENGINEER**	Architectural Chemical, Civil Mechanical Electrical Electronics	Basic Research Applied Research Process Development Quality Control Service-Sales Administration Cost Control
State College—Junior College 2, 3, or 4 years. Emphasis on broad and basic theory Science, Math, Engineering Subjects, Communication, Economics Not Pre-Engineering Associate Degree	**TECHNOLOGIST** Engineering Technician Engineering Assistant Science Technician	Specialization is Field Oriented Chemical, Civil, Mechanical, Electrical Electronics, Industrial Metallurgical	Planning-Drafting Computations-Estimating Tests-Evaluations Modifications Time Study-Safety Technical Writing Industrial Chemistry
Area-Vocational Technical Institute 2 years of Extension Courses, Lab-Shopwork Specific Skills, Tech. and Applied Knowledge Tools—Instruments—Controls Drafting—Calculations Diploma—Certificate	**TECHNICIAN** Industrial Technician Laboratory Technician	Specialization Areas: Manufacturing Construction Installation Instrumentation Customer Service	Drafting Estimating Surveying Testing Diagnosis
Area-Vocational Technical Institute 2 years or less Practical Pre-Employment Applied Science—Math Shopwork—Drafting Processes—Equipment Tools—Instruments Certificate—Diploma **Apprenticeship, 3 to 6 Years**	Production Technician Maintenance Technician **HIGHLY SKILLED CRAFTSMAN** **HIGHLY SKILLED INDUSTRIAL WORKER**	Manufacturing Construction Installation Maintenance Service Graphic Arts Building Trades	Tool & Die Makers Model Makers Set Up Man Lay Out Man Millwrights Mechanics Repairmen Draftsmen Carpenters Electricians Plumbers Sheet Metal Workers Welders Printers
Vocational Programs Pre-Employment Work-Study, Retraining	**MACHINE OPERATOR** **SEMI-SKILLED WORKER**	Manufacturing Transportation	Operators Fabricators Assemblers Inspectors Truck Drivers Helpers
On-The-Job	**UNSKILLED LABOR**	Manufacturing Construction Transportation Custodial	Handling Moving Loading Digging Cleaning

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GLOSSARY

1. *Customary System:* the system of measurement units (yard, pound, second, degree Fahrenheit, and units derived from these) most commonly used in the United States. Often referred to as the "English system" or the "U.S. system." Our customary system is derived from, but not identical to, the "Imperial system"; the latter has been used in the United Kingdom and other English-speaking countries, but is being abandoned in favor of the metric system.

2. *Metric System:* the measurement system that commonly uses the meter for length, the kilogram for mass, the second for time, the degree Celsius (same as "Centigrade") for temperature, and units derived from these. This system has evolved over the years and the modernized version today is identified as the "International System of Units," which is abbreviated "SI."

3. *International System of Units (SI):* popularly known as the modernized metric system, it is the coherent system of units based upon and including the meter (length), kilogram (mass), second (time), kelvin (temperature), ampere (electric current), and candela (luminous intensity), as established by the General Conference on Weights and Measures in 1960, under the Treaty of the Meter. A seventh base unit, the mole (for amount of substance) is being considered as another SI base unit. The radian (plane angle) and the steradian (solid angle) are supplemental units of the system.

4. *Metrication:* any act tending to increase the use of the metric system (SI), whether it be increased use of metric units or of engineering standards that are based on such units.

5. *Planned Metrication:* metrication following a coordinated national plan to bring about the increased use of the metric system in appropriate areas of the economy and at appropriate times. The inherent aim of such a plan would be to change a nation's measurement system and practices from primarily customary to primarily metric.

6. *Cost of Metrication:* that increment of cost, monetary or otherwise, directly attributable to metrication over and above any costs that would have been incurred without metrication.

7. *Benefits of Metrication:* monetary and other advantages accruing as a result of increased use of the metric system.

8. *Measurement Standard:* a device or physical phenomenon that is used to define or determine a characteristic of a thing in terms of a unit of measurement established by authority. Examples are gage blocks, weights, thermometers, and mean solar day.

9. *Engineering Standard:* a practice established by authority or mutual agreement and described in a document to assure dimensional compatibility, quality of product, uniformity of evaluation procedure, or uniformity of engineering language. Examples are documents prescribing screw thread dimensions, chemical composition and mechanical properties of steel, dress sizes, safety standards for motor vehicles, methods of testing for sulphur in oil, and codes for highway signs. Engineering standards are often designated in terms of the level of coordination by which they were established (e.g., company standards, industry standards, national standards).

In addition to the main glossary, we find the following terms need to be defined for this report:

Place value is the concept that a numeral represents a certain value depending upon its place in a number. For example, the numeral "2" in 7521 means "20" in the sum 7000 + 500 + 20 + 1, while in 7251 it is in a different place and has a different value.

Binary fractions are fractions with power-of-2 denominators: halves, quarters, eighths, sixteenths, etc.

Full Titles of References Identified by Short Names in the Body of the Report.

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A white paper will be published by the British Government in the spring 1971: it will present the Government's position for a parliamentary debate.

Metric Change in India, edited by Lal C. Verman and Jainath Kaul. Indian Standards Institution, New Delhi. Essays by a number of the civil servants who were engaged in the Indian program of introducing a decimal coinage and the metric system – a program now all but complete.

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"Metrication in Schools II; Report of Conference on 19 September 1968," London, The Royal Society, January 1959, 59 pp. Key papers and discussion of them.

"Metric Units in Primary Schools," The Royal Society, September 1969, 29 pp. Background material and educational implications.

"Metrication in Secondary Education," The Royal Society, 1969, 12 pp. Background material and educational implications.

"Change for a Pound," Schools Council, London, Her Majesty's Stationery Office, September 1968, (revised edition, January 1970), vii + 51 pp. This pamphlet deals with metric weights and measures as well as the decimal coinage. It describes teaching experiences and tactics and strategies; and sets forth the implications for mathematics and other subjects together with recommendations. [The Schools Council is a curriculum development and coordination arm of the national education establishment.]

"Measure for Measure: a Guide to Metrication for Workshop Crafts and Technical Studies," Schools Council, London, Evans Brothers

Limited/Methuen Educational Limited, February 1970, 62 pp. This pamphlet is a complement to the one above, and outlines in some detail schedules for changes in metal- and wood-working shops and in technical drawing. It describes the experience of one school and discusses in a general way the problems of developing metrication in a coordinated way, especially regarding the supply and demand of vocationally trained workers.

"Introduction of SI Units in Schools," published by the Mathematical Association, (no date), 25 pp.

"SI Units, a Guide for Teachers," The City of Bradford (Yorkshire) Corporation, 1970, 24 pp. A mixture of authoritative facts and informal notes and suggestions for teaching tactics, with several pages of familiarization exercises for adults (teachers) which can be performed in an hour or two.

"Metrication II; The Teacher and the Transition Period," Kent County Council/Kent Education Committee, Maidstone, September 1970, 24 pp. This pamphlet is similar to the one directly above, but different in tone. The concepts of mass, weight, and force are discussed in some detail. Separate booklets on the various academic subjects are promised.

"Machine Tools for Metric Production," Machine Tool Industry Research Association, (no address), November 1968, 24 pp. This booklet outlines the factors to be considered by machine tool users; it has drawings of dual-dial feed-screw indicators and a list of manufacturers of conversion equipment.

"Metrication, Decimalization, and SI Units," Association of Teachers in Technical Institutions, September 1969, 16 pp. Mainly a compilation of definitions, standards of usage, and conversion factors.

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This publication concerns the effects of increasing worldwide use of the metric system on education in the United States. The study was carried out and the report prepared for the U.S. Metric Study by the Education Development Center in Newton, Massachusetts. The aims of this education study were fourfold: (1) to assess the educational advantages and disadvantages of both the metric and the customary systems of units, (2) to determine the current usage of metric measures in U.S. schools and trends in that usage, (3) to find the ways in which education would have to change as the U.S. accomodates to increased worldwide use of the metric system, under a laissez faire or a planned approach, and estimate the costs of the changes, and (4) to make recommendations of ways in which to take best advantage of said changes. The report also discusses and suggests ways of achieving curriculum changes needed in view of increasing metric usage. The publication includes the program of the Education Conference, held in October, 1970, as one of a series of National Metric Study Conferences, and the texts of the key papers presented at that conference by the National Education Association and the National Science Teachers Association.

17. KEY WORDS (Alphabetical order, separated by semicolons) education; International System of Units; metric conversion; metric system; metric usage; metrication; metrication, attitudes toward; metrication, costs and benefits of; metrication, impact of; SI; U.S. Metric Study

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